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Payload Crew Utilization for Spacelab Missions

**K. Y. Ibrahim
and J. D. Weiler**

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National Aeronautics and
Space Administration
Office of Management
Scientific and Technical
Information Division

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TECHNICAL PAPER

PAYLOAD CREW UTILIZATION FOR SPACELAB MISSIONS

BACKGROUND

The amount of crew time scheduled for payload operations is a major resource driver in mission design that is directly related to science return and operational flexibility. Traditionally the payload timeline evolves through several iterations in the mission design process, increasing in fidelity as experiment operational requirements and mission constraints mature. In order to accommodate these changes in requirements and constraints, it is important to maintain adequate crew time margins through each major mission design review. Failure to do this can result in deletion/descoping of experiments and/or limited replanning flexibility both pre-mission and during real-time operations.

PURPOSE

The purpose of this study was to analyze the payload crew utilization for each major timeline iteration in the mission design process. This has been accomplished by analyzing preflight Spacelab mission timelines to determine approximate percentages of crew utilization at the major timeline iterations. As-flown data have not been included.

SCOPE

This study is applicable only to Spacelab missions and is based on available mission data. Data were obtained and analyzed for the following missions: SL-1, SL-2, SL-3, Astro-1, Starlab, Atlas-1 (EOM), IML-1, SL-J, SLS-1, and D-2.

Although missions generally have several timeline versions as they progress through mission design, four major iterations may be identified for comparison and analysis of data. Recommendations provided are generic in nature and should be considered against current crew scheduling constraints, elapsed time available on a given shift, crew skill mix, and mission unique requirements.

STUDY DESIGN/APPROACH

A standard basis of comparison was established utilizing a generic mission format of four payload crew members and four major timeline iterations.

Crew Complement

The payload crew on a given Spacelab mission consists of both Payload Specialists (PS) and Mission Specialists (MS). The PS are solely dedicated to the accomplishment of payload activities while MS are also assigned specific system/subsystem responsibilities. Therefore, the payload MS cannot be scheduled for payload activities to the same level as the PS, however, on a nominal mission the payload MS can be equally available for payload activities. Orbiter crewmembers are often invaluable in the attainment of payload objectives, including maneuvering the orbiter to support payload requirements. Orbiter crews have not been included in this study, however, due to the fact that their availability is at the discretion of the mission commander based on real-time conditions.

Four payload crewmembers, two PS and two MS, were utilized as the standard basis of comparison for this analysis. In the case of three PS or MS, the two most heavily utilized crewmembers were selected. For the purpose of this study, the payload crewmembers are referred to as one of the following: PS-1, PS-2, MS-1, and MS-3. The numbered designations refer to duties and seating assignments on-board the orbiter. MS-2 is typically a flight engineer or back-up pilot.

Timeline Iterations

Missions proceed through a succession of integrated payload (IPL) reviews, each of which reflects increases in mission fidelity and maturity. At the onset of the mission design process there is an IPL Requirements Review (RR) for the purpose of establishing basic mission compatibility with the preliminary science complement. Following this review there is an IPL Preliminary Design Review (PDR) and an IPL Critical Design Review (CDR) for the purpose of reviewing the initial and final designs. The IPL Flight Operations Review (FOR) and the Flight Readiness Review (FRR) are major reviews that certify the mission ready for flight. Major timeline iterations are keyed to these reviews and reflect increases in detail and reality as science procedures/hardware are developed, crew training progresses, and NSTS/mission constraints finalize.

The RR timeline iteration occurs at approximately L-36 months to support the RR. A preliminary timeline iteration is accomplished between L-36 and L-25 months to support the IPL PDR, and from L-24 to L-13 months a basic timeline iteration supports the IPL CDR, and Payload Flight Operations Review. A final timeline iteration occurs during L-12 to L-5 months to support the National Space Transportation System (NSTS) FRR and flight. These major iterations were utilized for comparison and analysis of data contained in this study.

METHODS

The majority of data was obtained from timelines generated by the Experiment Scheduling Program (ESP). For some of the early missions, detailed data were not available for the initial timelines. In some cases (e.g., SL-1, SLS-1) data not available in ESP were retrieved manually from the Payload Timeline Summary (PTS) charts.

The timeframe utilized for crewmember activity was from one shift handover to the next, including the meal period and excluding pre/post sleep periods. This formed the basis for the total time available. Crew time percentages were calculated per flight day, mission, and iteration. Flight day is a time reference relating to a crewmember's work/rest cycle. Flight day one (FD1) begins at launch with subsequent flight days beginning at crew wake-up and continuing through the sleep period. A flight day typically represents a 24-hour period that encompasses one shift's duty period and another shift's rest period.

Percentage of Crew Time Per Day

The percent crew time per day was calculated by dividing the total crew scheduled time (including the meal) per crewmember by the shift duration. The calculations utilized are as follows:

Crew Scheduled Time = Time crewmember is scheduled to conduct activities for a given day, including the meal

Shift Duration = Duration of a given shift from handover to handover, including the meal (normally 12 hours)

$$\frac{\text{Crew Scheduled Time}}{\text{Shift Duration}} * 100 = \text{Percent Crew Time Per Day}$$

Percentage of Crew Time Per Mission

The percent crew time per mission was determined by calculating an average percent crew time value per crewmember per mission. This was performed by adding the percentages for all days per crewmember and then dividing by the number of days.

Percentage of Crew Time Per Timeline Iteration

The percent crew time per timeline iteration was determined by calculating the average crew time per mission on an iteration by iteration basis. This was performed by adding the percentages for all missions per crewmember and dividing by the number of missions.

RESULTS

The detailed tabular results of the aforementioned analyses are presented in Appendix A in Tables 1 to 21. The data are provided in percent crew utilization by crewmember, flight day, mission, and iteration. Tables 1 to 16 provide the percentage of crew time per day for each crewmember categorized by mission and iteration. The average percentage of crew time per day per crewmember is provided for each iteration including maximum and minimum values. Tables 17 to 20 provide summaries of the percentage

of crew time individual crewmembers were scheduled over an entire mission, categorized by iteration. Also included are the average percentage of crew time crewmembers were scheduled for each iteration plus maximum and minimum values. Table 21 presents a summary of the overall results by providing the percentage of crew utilization by crewmember at the major timeline iterations.

Figures 1 to 30, included in this section, graphically depict the tabular data resident in Appendix A. Figures 1 to 25 present bar graphs of crew utilization for the PDR, basic, and final iterations by flight day for each crewmember. The graphs illustrate the percent of crew utilization for each applicable mission. The RR iteration was not included since only one case (SL-J) was reported. Figures 26 to 29 provide graphic summaries of individual crew utilization for the PDR, basic, and final iterations. The data are presented by flight day and include average, maximum, and minimum values. Figure 30 presents a final summary bar chart of crew utilization for each of the three major iterations with average, maximum, and minimum utilizations.

Certain table and graph entries are blank, reflecting either a lack of the applicable mission data or nonexistence of data (e.g., a 7-day versus a 9-day mission).

CONCLUSIONS

Based on the results of this study, recommended crew utilization guidelines have been formulated for timeline iterations. Guidelines have also been developed for standard calculation of crew utilization. These guidelines must be considered against crew scheduling constraints, science constraints, crew composition, and mission unique requirements.

Analysis of the results of this report depicts an overall trend of lower crew utilization in the early iterations with maximal utilization being approached at the basic timeline iteration and being reached at the final iteration. Although the RR iteration shows a higher utilization than the PDR iteration, the RR iteration was based on only one mission, SL-J, and thus is not considered representative. Average crew utilization for the final iteration is approximately 60 percent over all missions. Maximum utilization, averaged for all crewmembers, approached 72 percent on SL-2 for the final iteration.

Considering the results of this report plus operational experience, it is recommended that for the RR and PDR iterations the maximum per shift utilization should be 75 percent for the PS and 65 percent for the MS; and for the basic and final iterations, the maximum per shift utilization should be 85 percent for the PS and 75 percent for the MS.

Total time available is the time from shift handover to handover (not inclusive) for dual shift missions and from postsleep to presleep (not inclusive) for single shift missions. The time available includes provision for lunch and exercise. The reduced percentage for the MS reflects the additional requirement for 2 hours of availability for STS activities. Historically these 2 hours have not generally been implemented. The MS could actually be scheduled for approximately 91 percent of the total time available if the 2 hours reserved for STS activities were required.

Based on these criteria, at the final iteration, the PS on a nominal 12-hour shift would have 1 hour for lunch, 1 hour for exercise, and up to approximately 8.2 hours for payload activities. The payload MS on a nominal 12-hour shift would have 1 hour for lunch, 2 hours available for STS activities, 1 hour for exercise (FD2 through day prior to landing), and up to approximately 7.0 hours for payload activities.

Operational experience has indicated that crewmembers frequently experience decreased functional workload and Space Adaptation Syndrome (SAS) symptomatology during the first 48 hours of on-orbit operations. For this reason it is recommended that whenever possible, without compromising science, crew workload which can be offloaded from flight days 1 and 2 be scheduled later in the mission.

It is also recommended that a standard method of calculating, analyzing, and presenting crew time data be established for all missions. A major problem in the analyses of the available data was the different approaches and methods used. This necessitated much manual analysis and some interpretation. The following guidelines have been developed as a recommended method for the future calculation, analysis, and presentation of crew time data.

1. Crew time available is calculated from shift handover to handover (not inclusive) for each crewmember for each shift.
 - Include elapsed time for lunch, exercise, and daily planning.
 - Exclude time for handover, sleep, presleep, and postsleep.
 - PS are schedulable for up to 10 hours for payload activities plus 1 hour lunch and 1 hour exercise (when required).
 - Payload MS are schedulable for up to 8 hours for payload activities plus 1 hour for lunch, 1 hour for exercise (FD2 through day prior to landing) and 2 hours for MS STS activities.
 - Specific availabilities were dependent on mission crew duty cycle (nominal availability is 12 hours per shift) and utilization guidelines.
2. Crew time scheduled includes lunch, daily planning, and exercise.
 - Excludes handover, sleep, presleep, postsleep, and 2 hours for STS activities.
3. Intrusions into pre/post sleep are identified as separate line items and are not factored into availability or utilization.
4. Orbiter crew payload activity is tracked in total hours per type of activity (no percentages).
5. First shift starts at the end of Payload Activation and the last shift ends at the beginning of Payload Thermal Conditioning (PTC) attitude.
 - Any payload activity during Spacelab Activation/Deactivation is tracked separately.

6. Payload crew utilization data are provided in: hours scheduled per crewmember/shift with percent utilization in parentheses; and hours scheduled per crewmember/mission with percent utilization in parentheses.

- Percent utilization = crewtime scheduled/crew time available.

- Hours per crewmember/mission based on a summation of individual shifts.

It is recognized that each mission may have unique requirements necessitating additional data analysis formats and possibly modifications to these guidelines. When these circumstances arise, differences from the aforementioned guidelines should be properly documented.

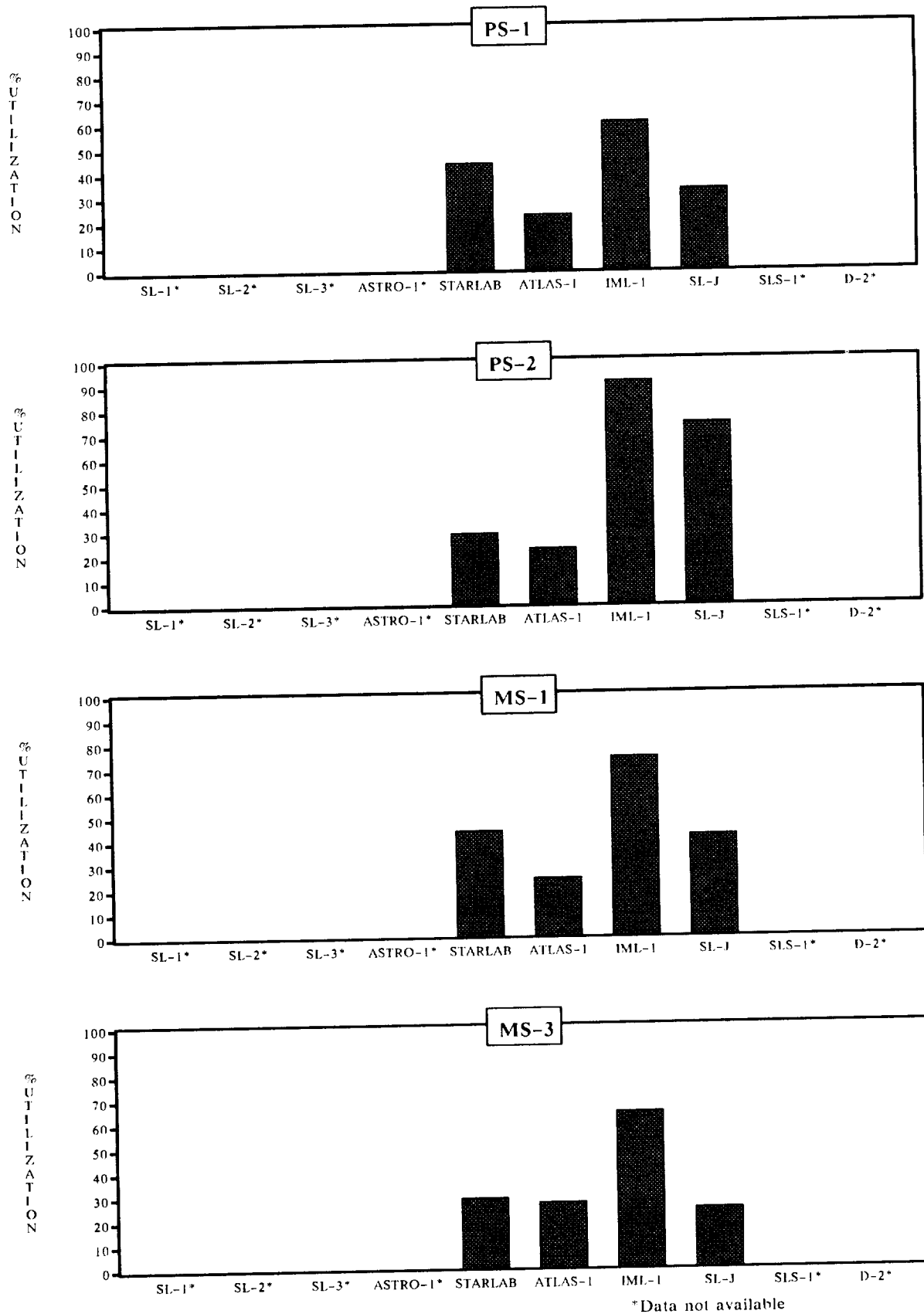


Figure 1. PDR iteration FD1 crew utilization

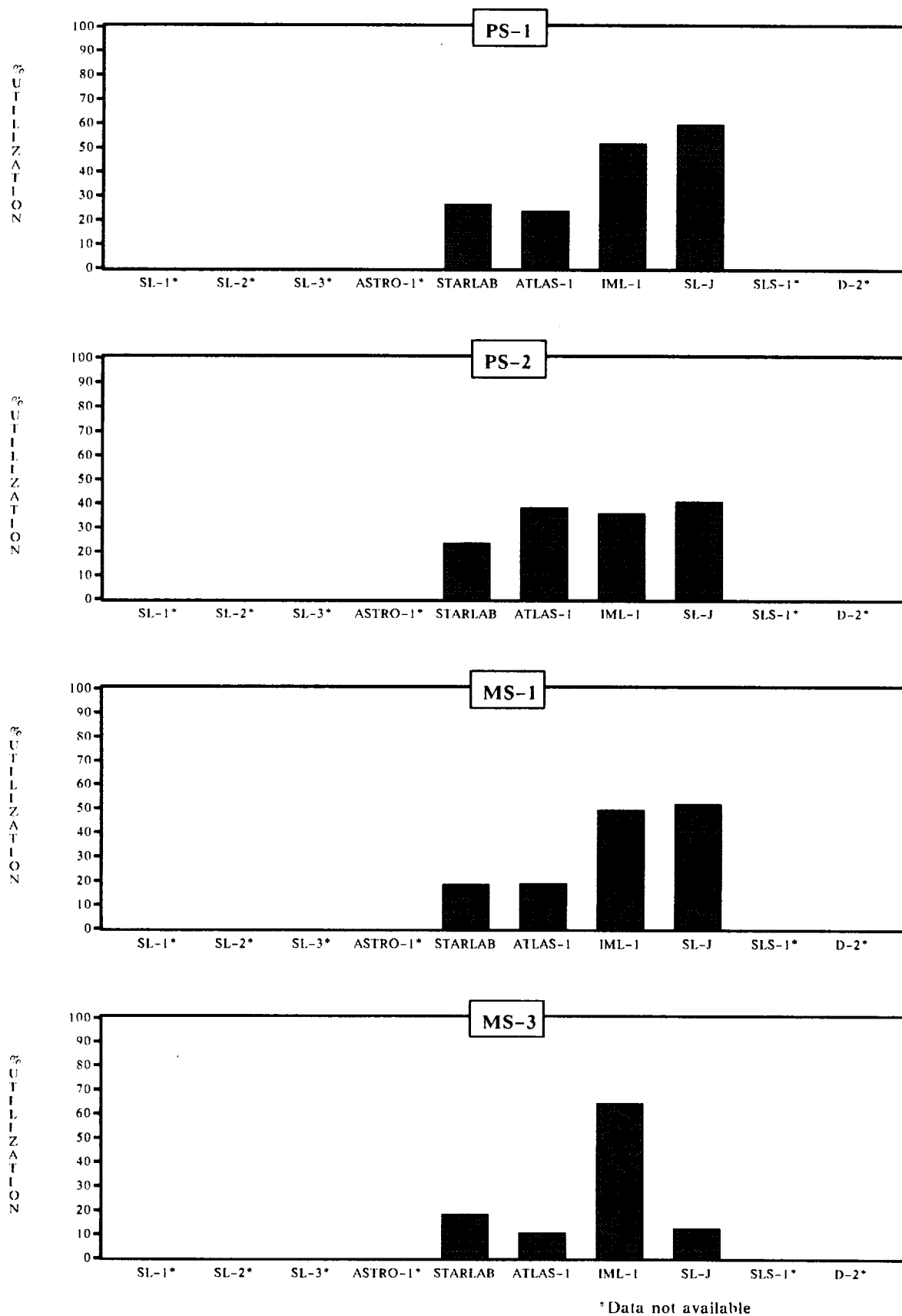
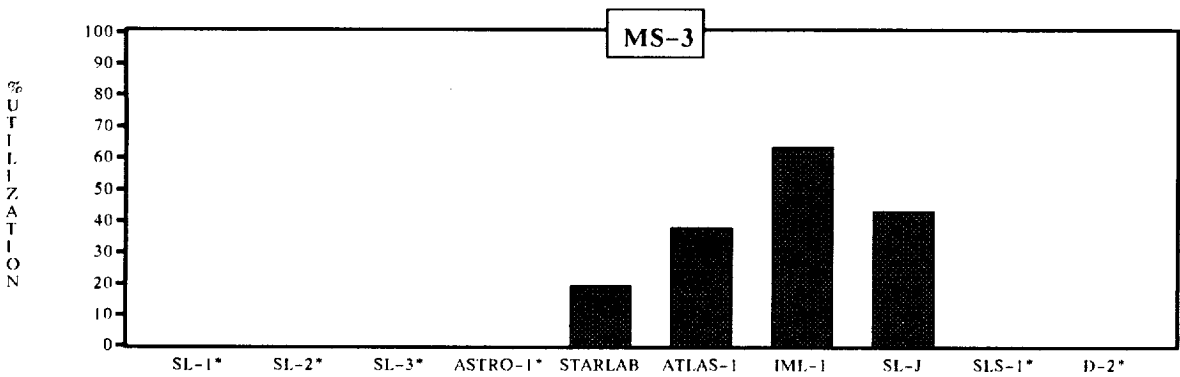
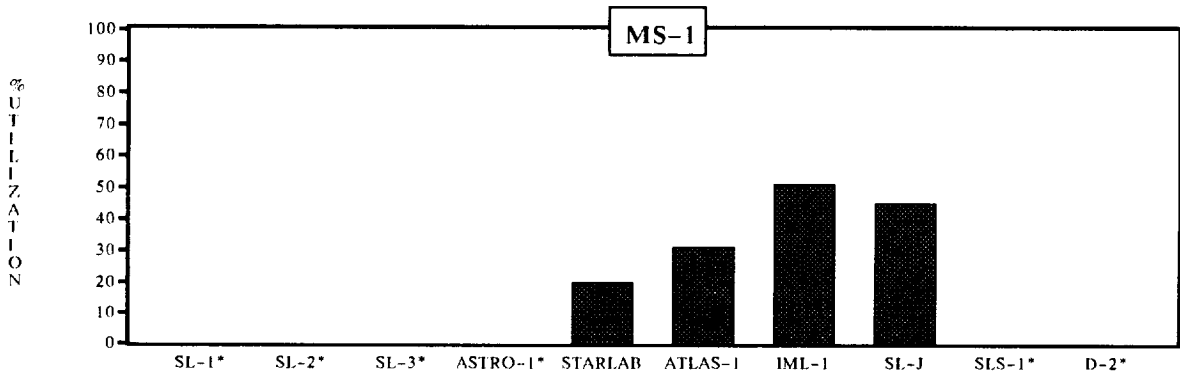
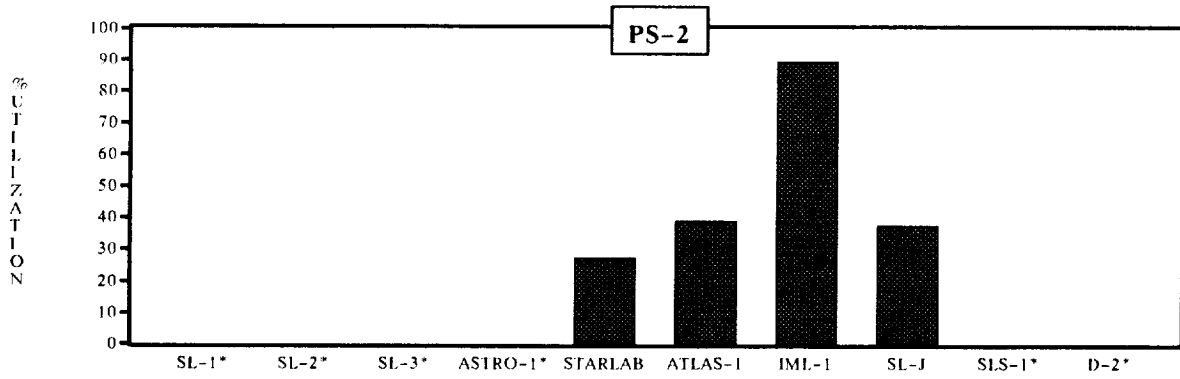
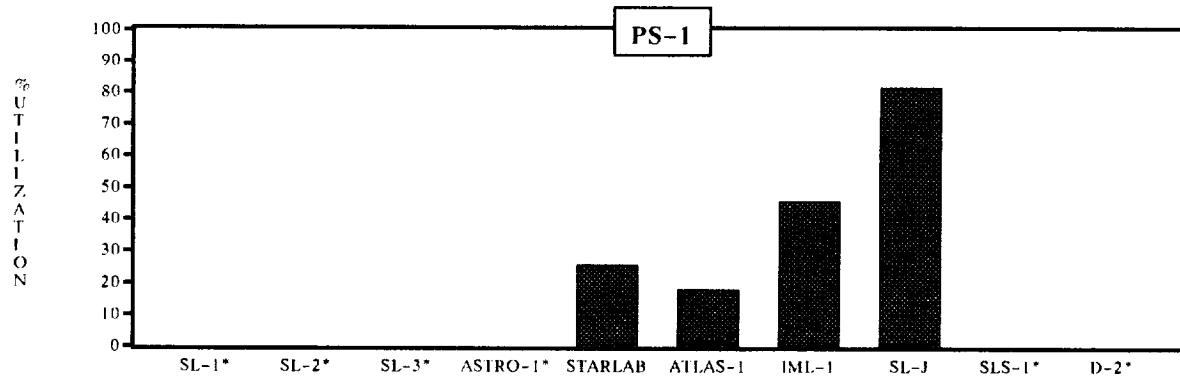


Figure 2. PDR iteration FD2 crew utilization.



*Data not available

Figure 3. PDR iteration FD3 crew utilization.

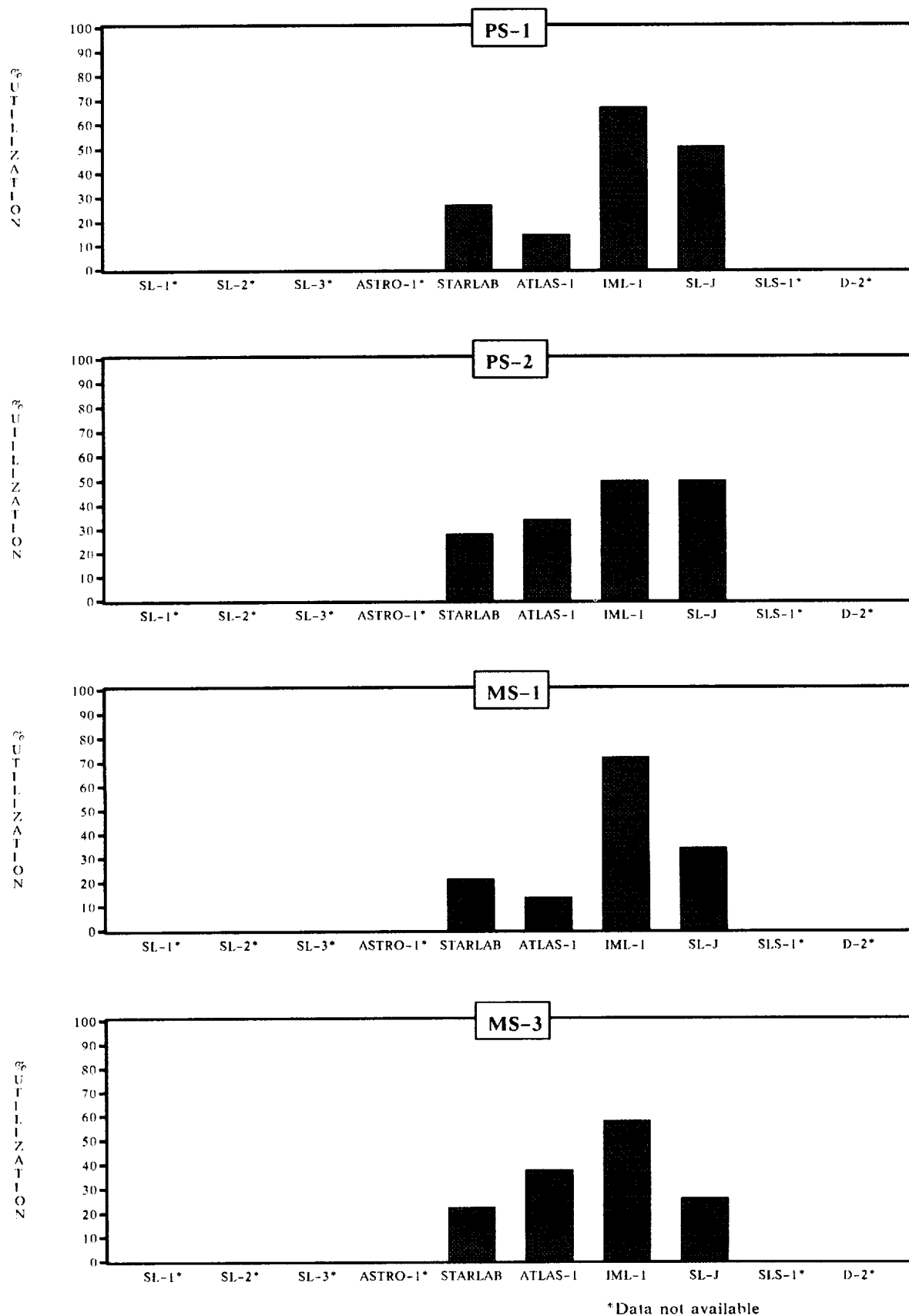


Figure 4. PDR iteration FD4 crew utilization.

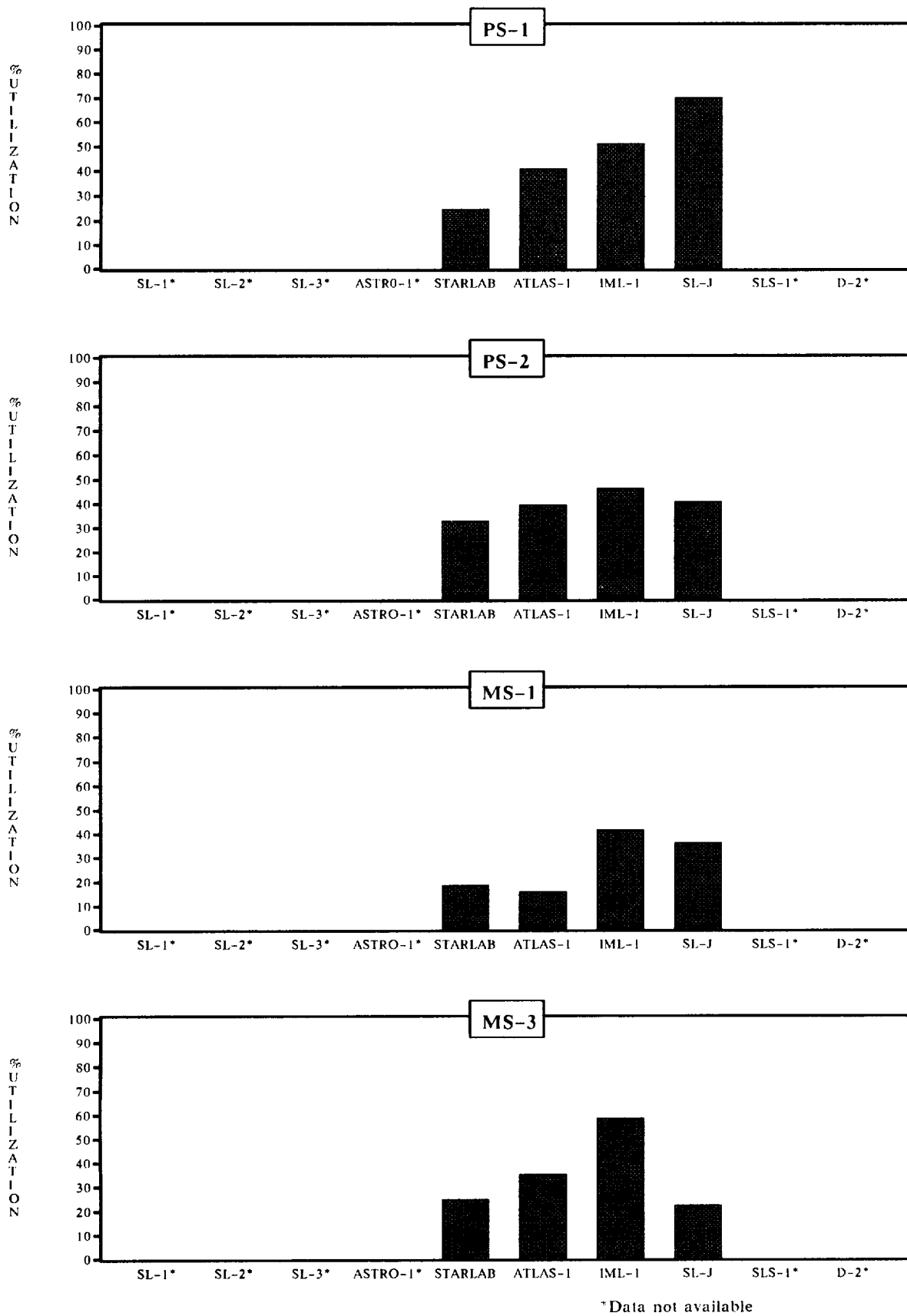


Figure 5. PDR iteration FD5 crew utilization.

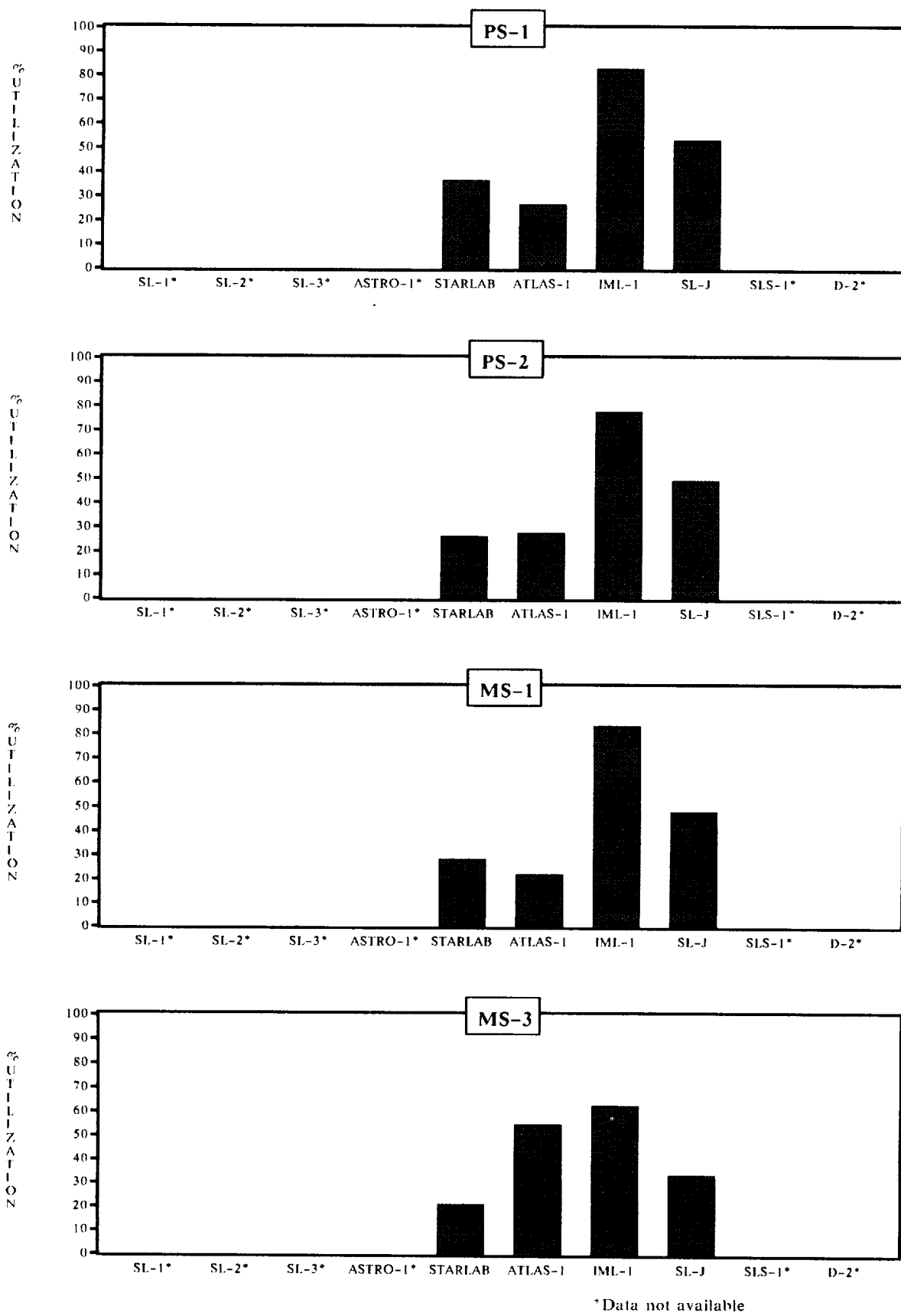


Figure 6. PDR iteration FD6 crew utilization.

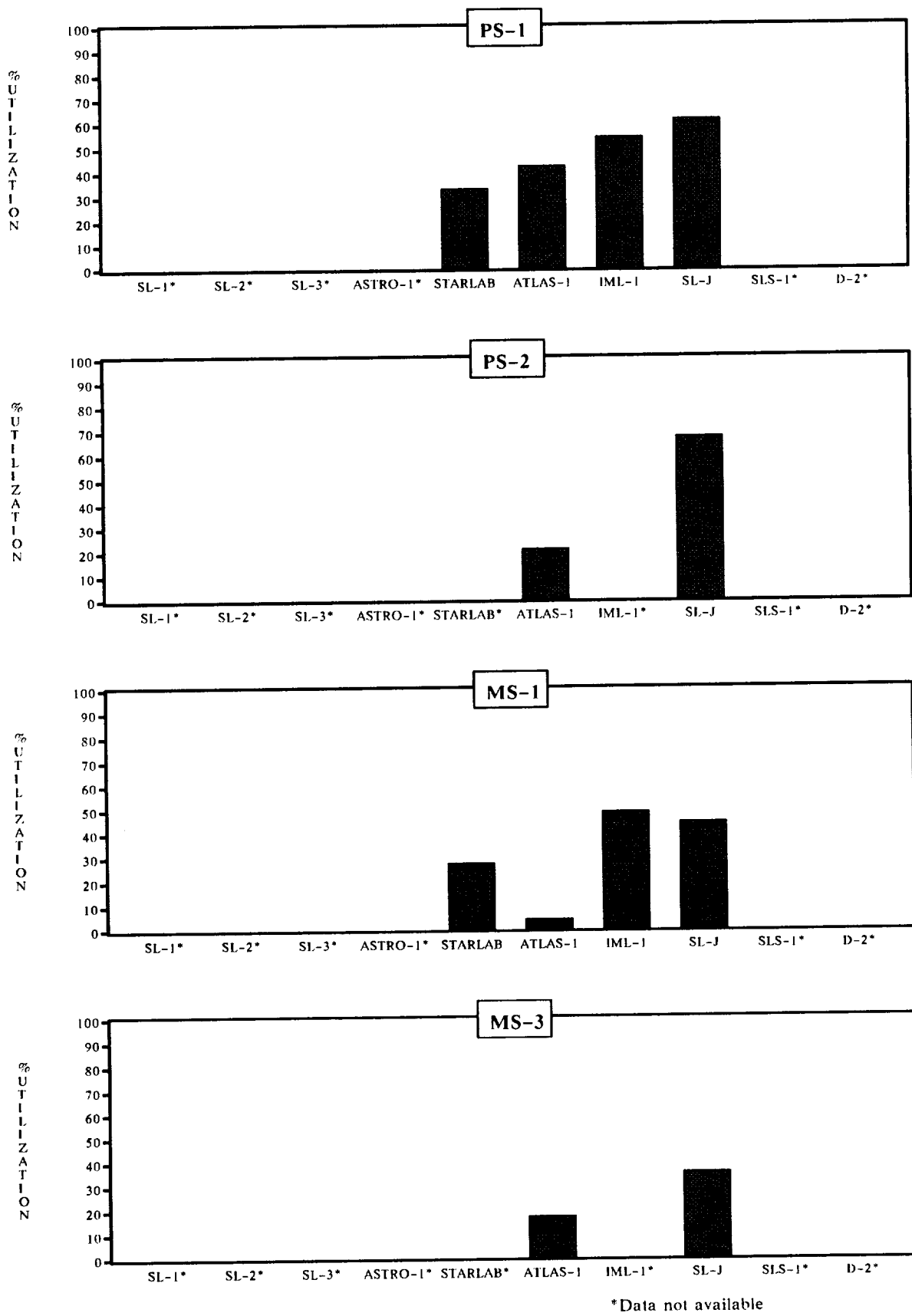


Figure 7. PDR iteration FD7 crew utilization.

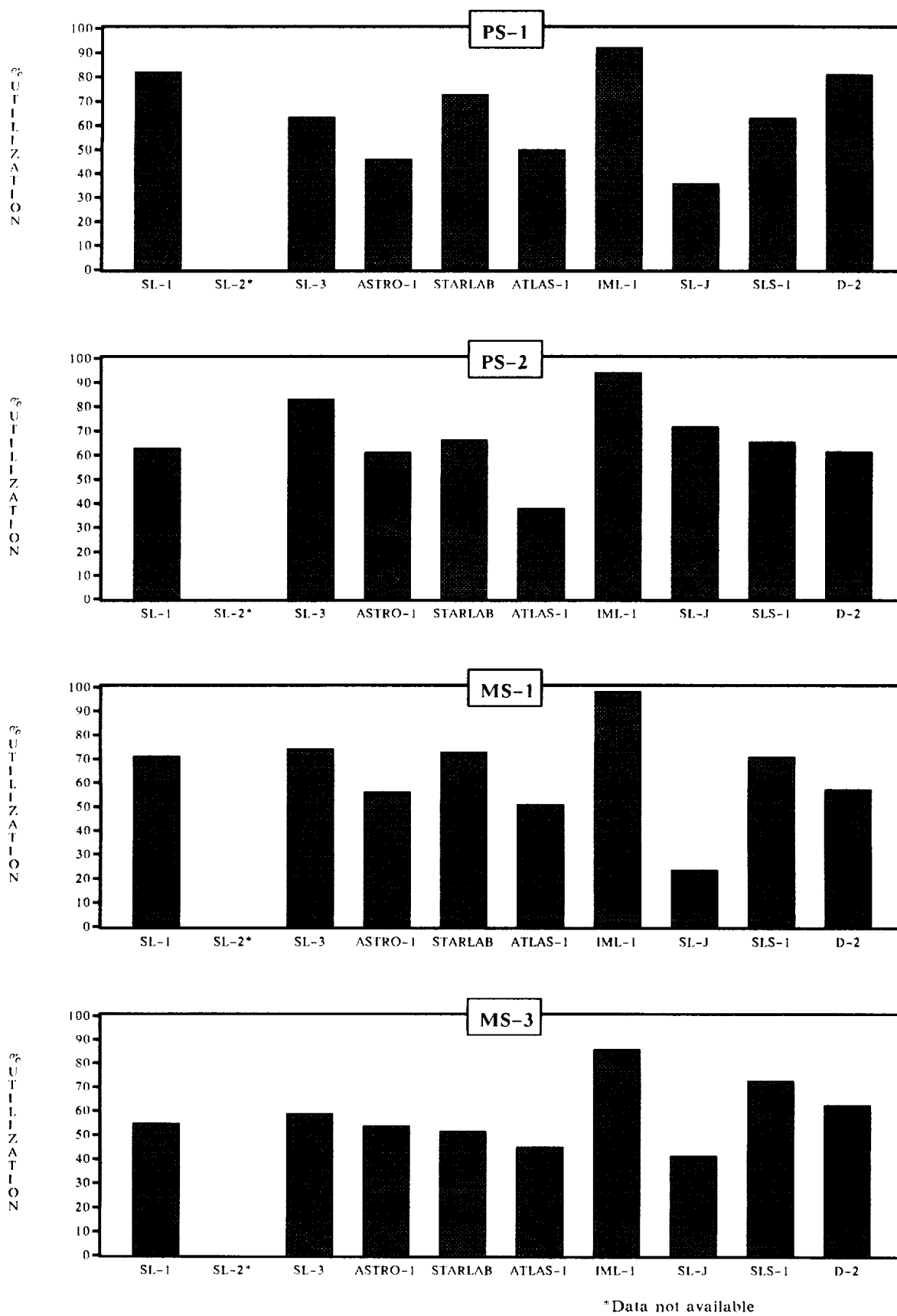
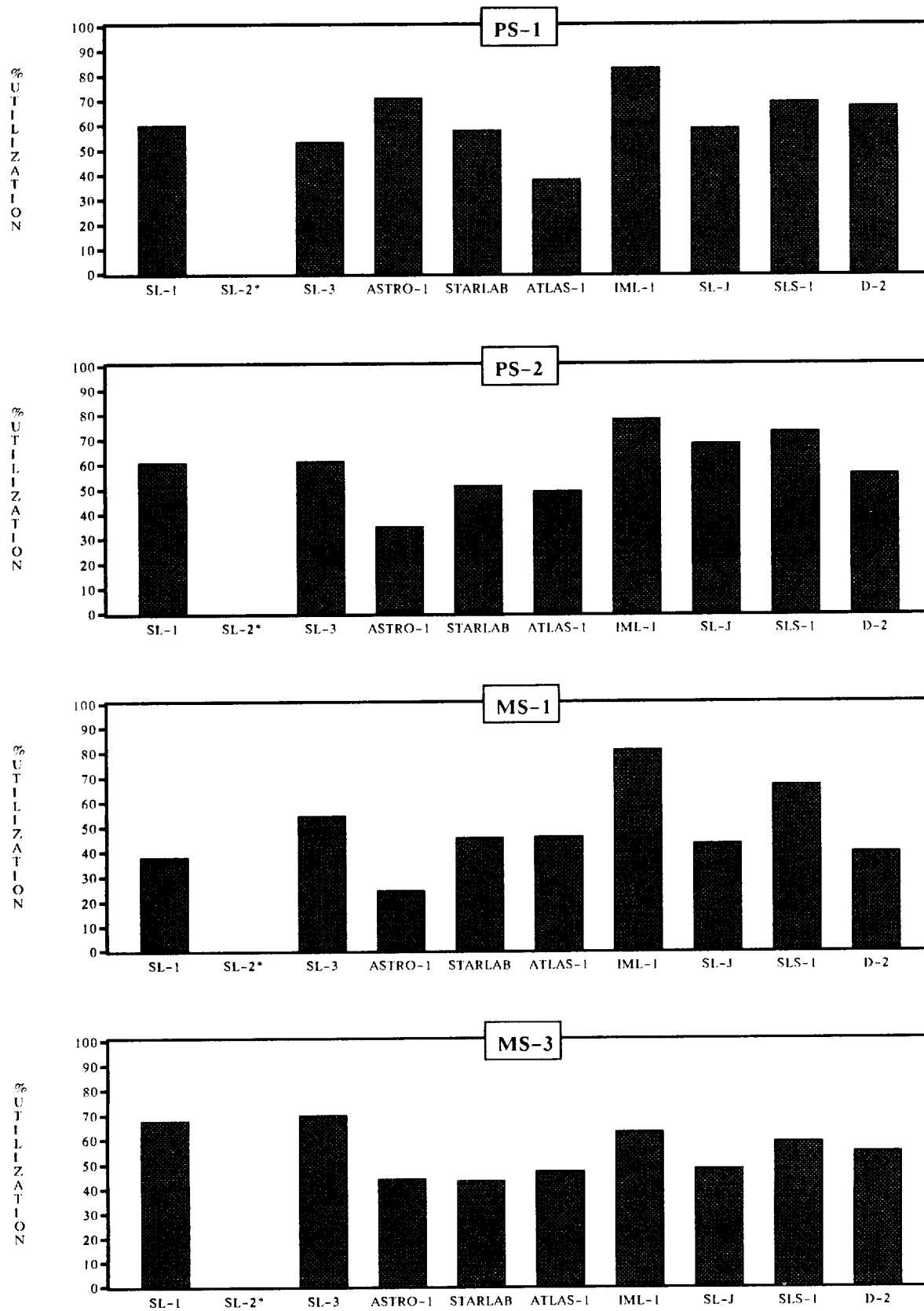
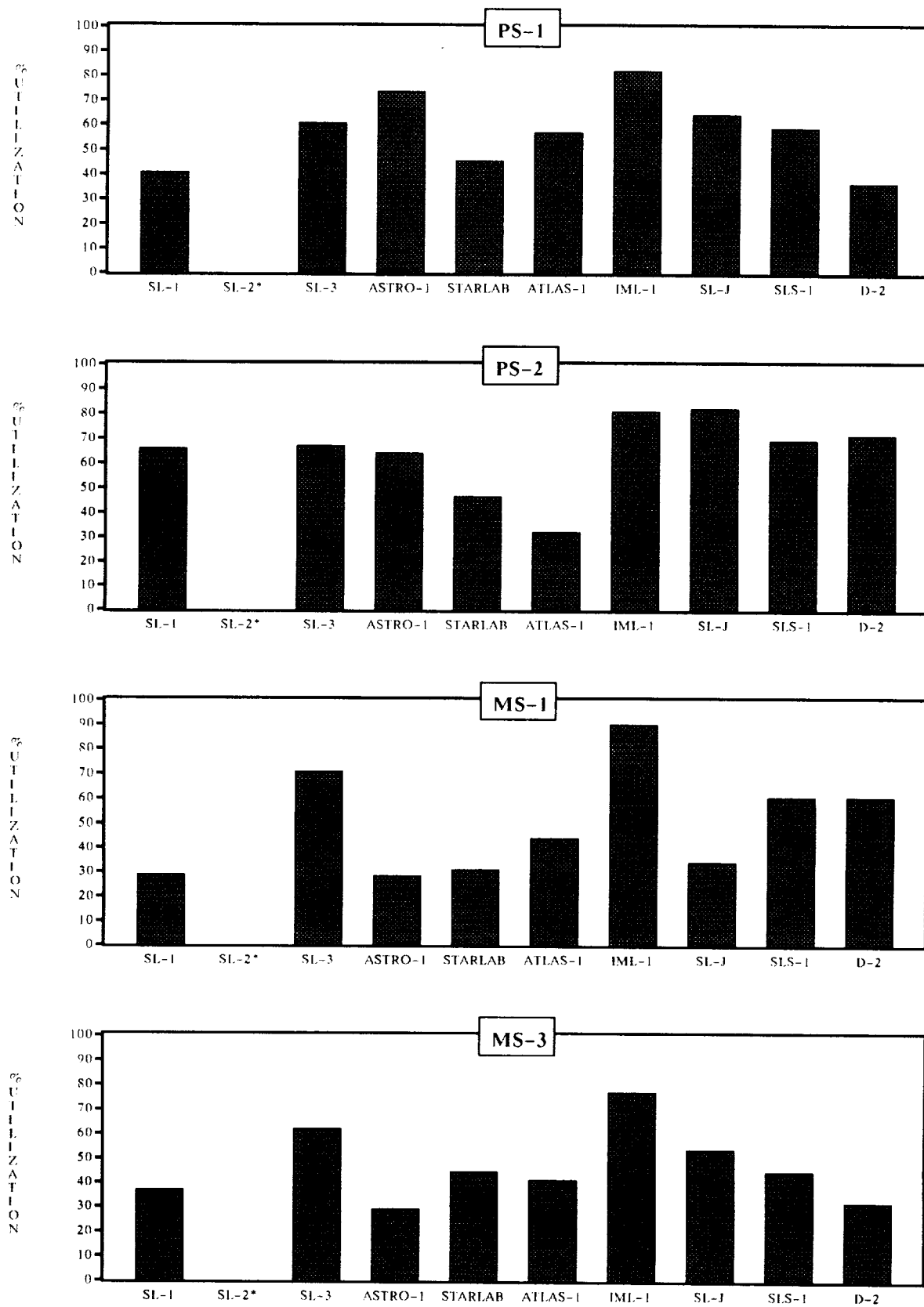


Figure 8. Basic iteration FDI crew utilization.



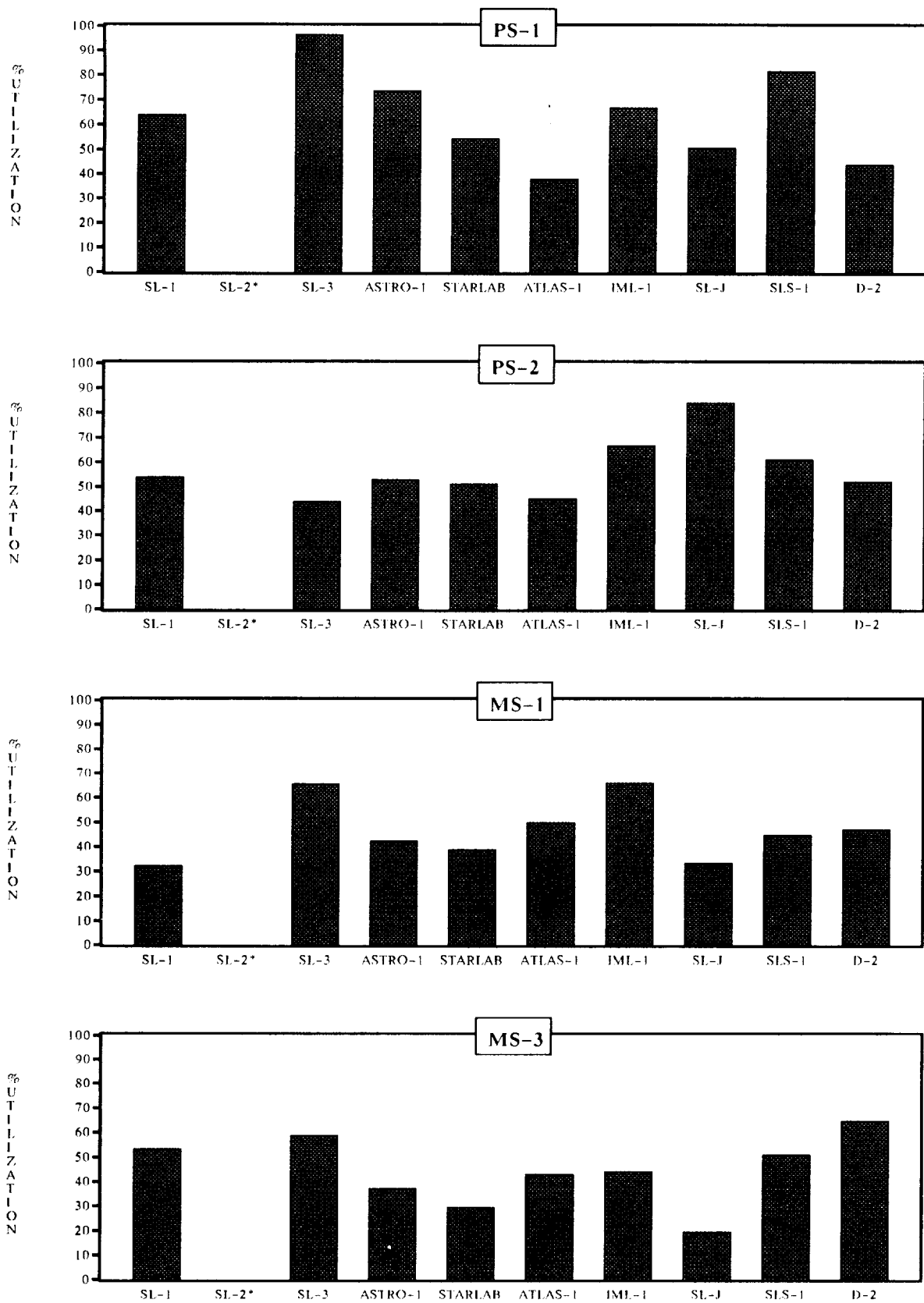
*Data not available

Figure 9. Basic iteration FD2 crew utilization.



*Data not available

Figure 10. Basic iteration FD3 crew utilization.



*Data not available

Figure 11. Basic iteration FD4 crew utilization.

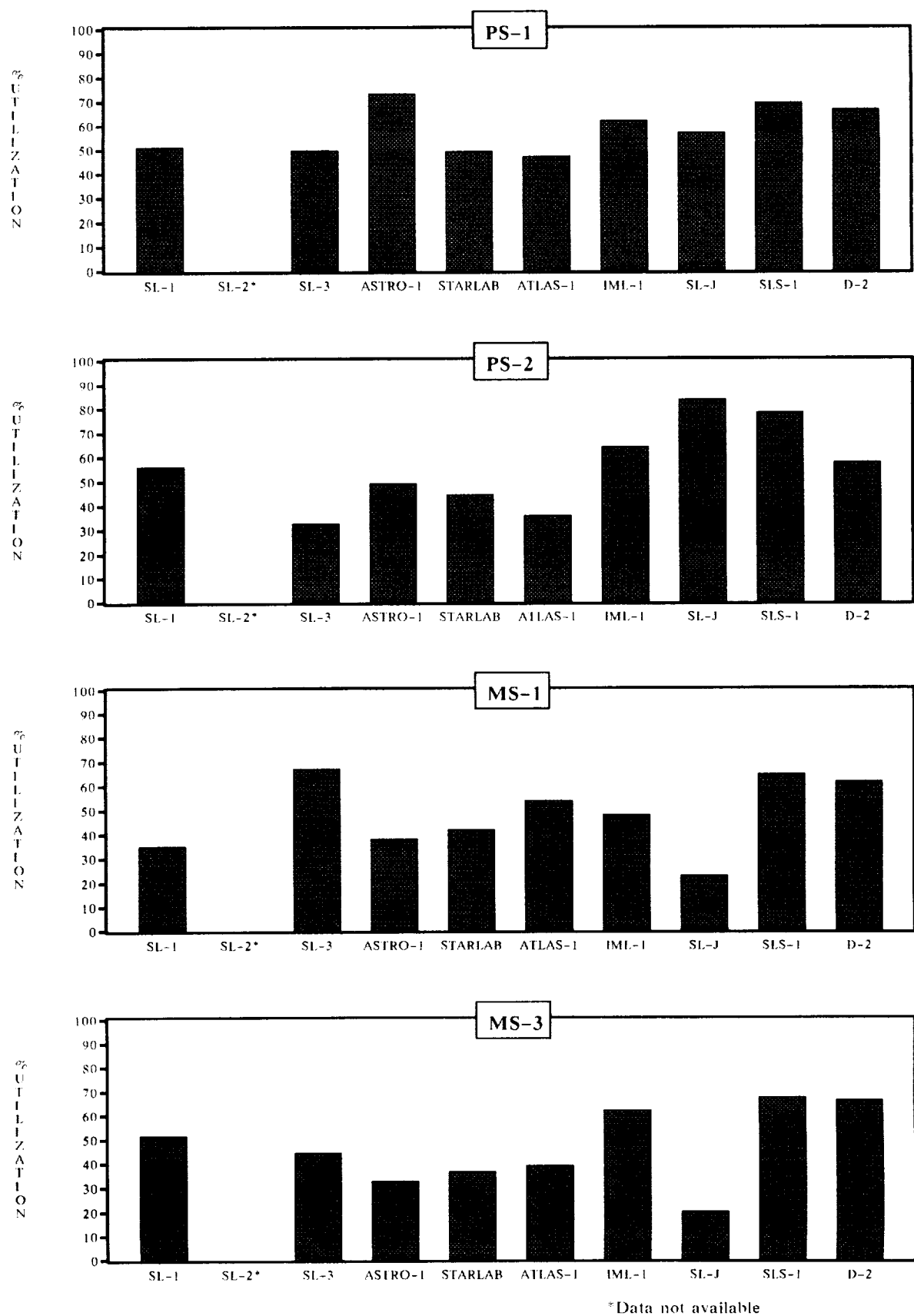


Figure 12. Basic iteration FD5 crew utilization.

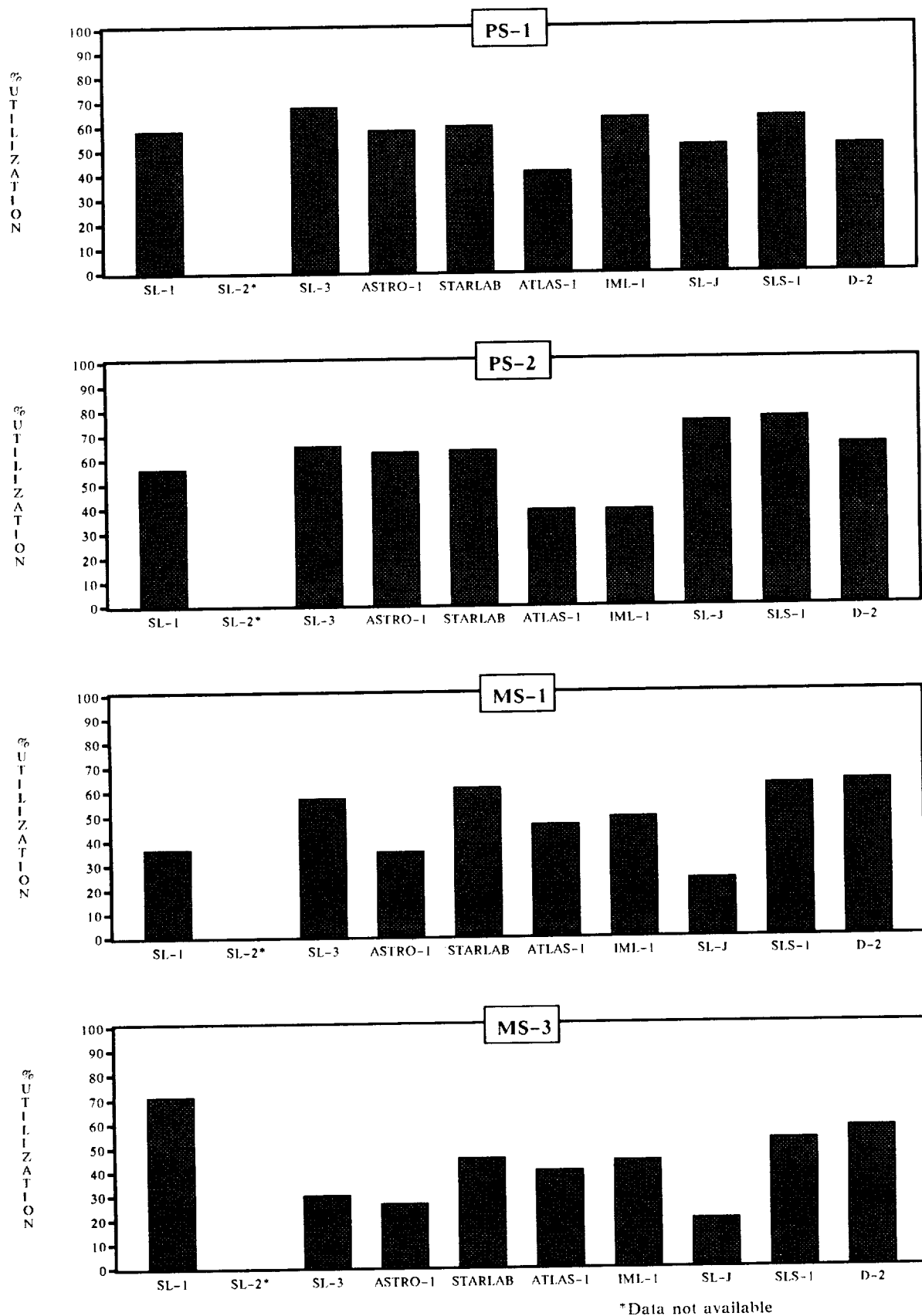


Figure 13. Basic iteration FD6 crew utilization.

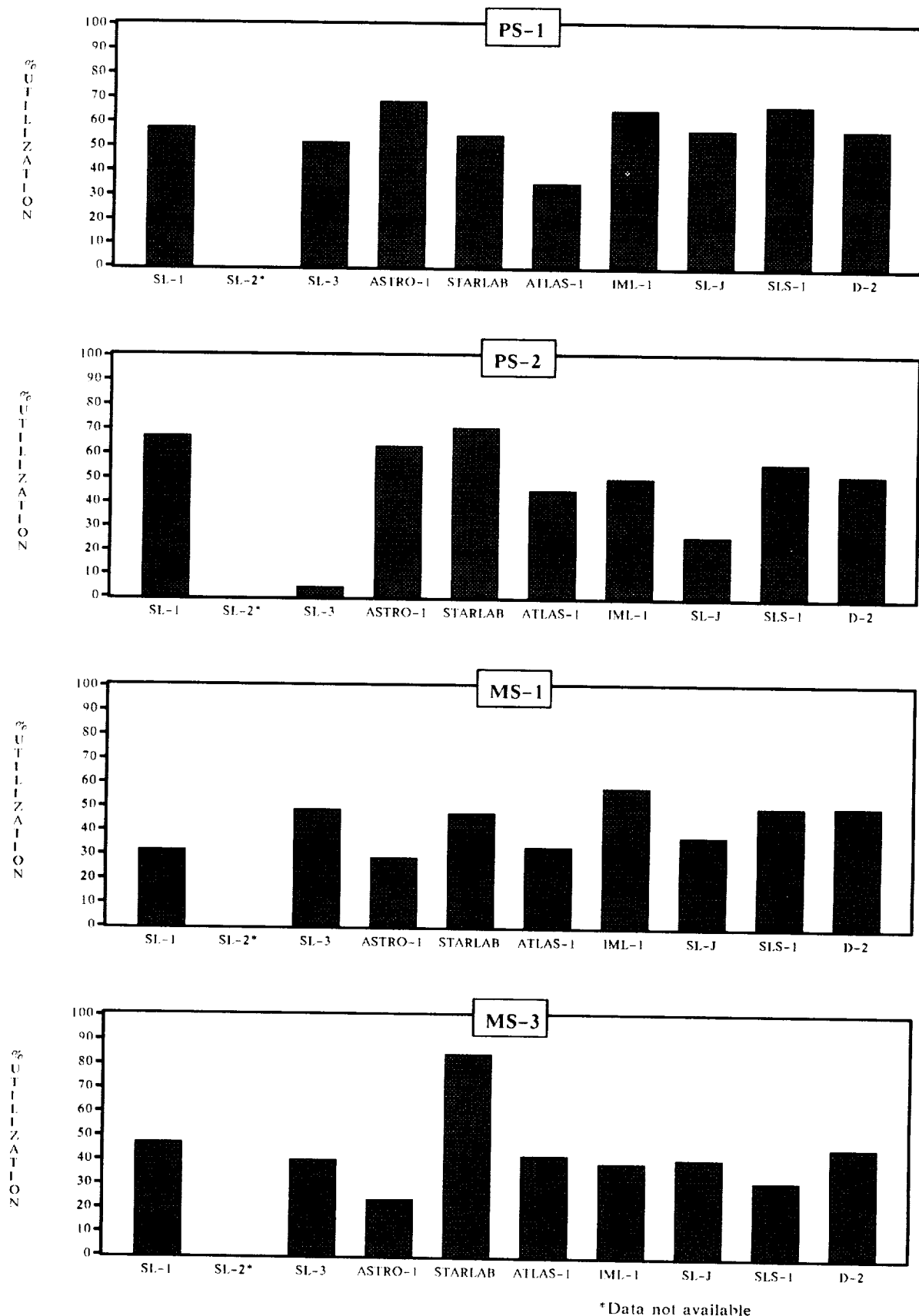


Figure 14. Basic iteration FD7 crew utilization.

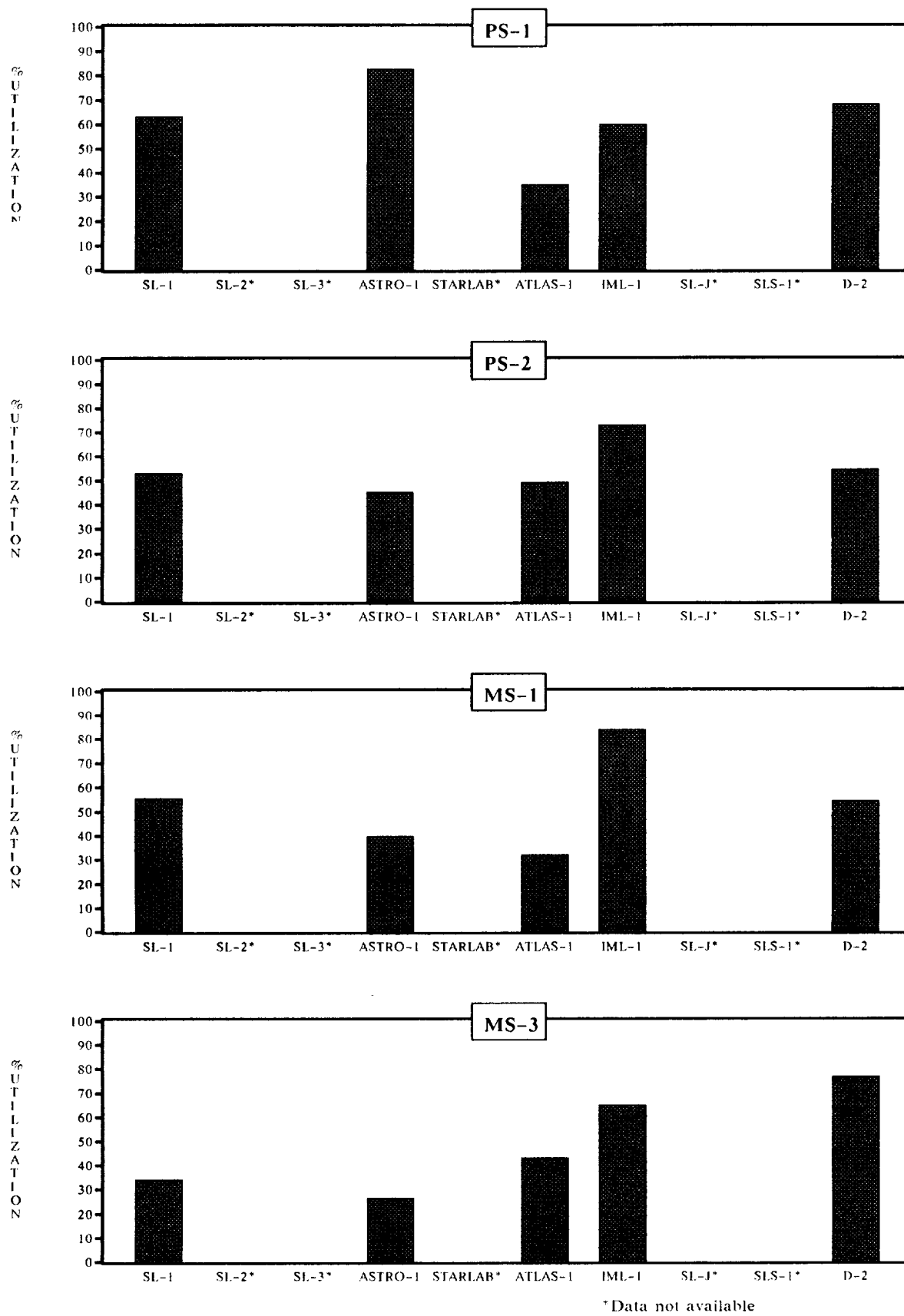


Figure 15. Basic iteration FD8 crew utilization.

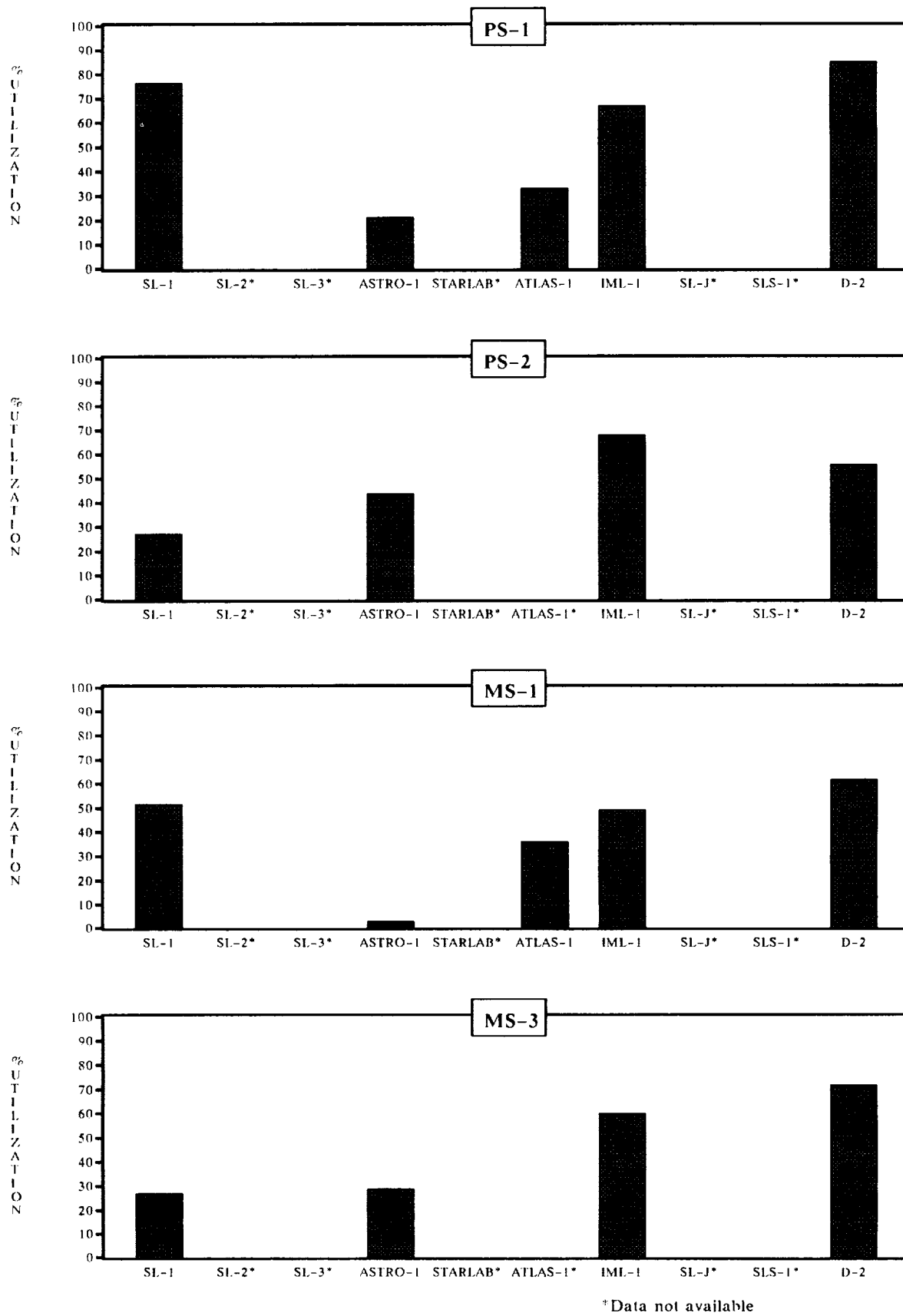


Figure 16. Basic iteration FD9 crew utilization.

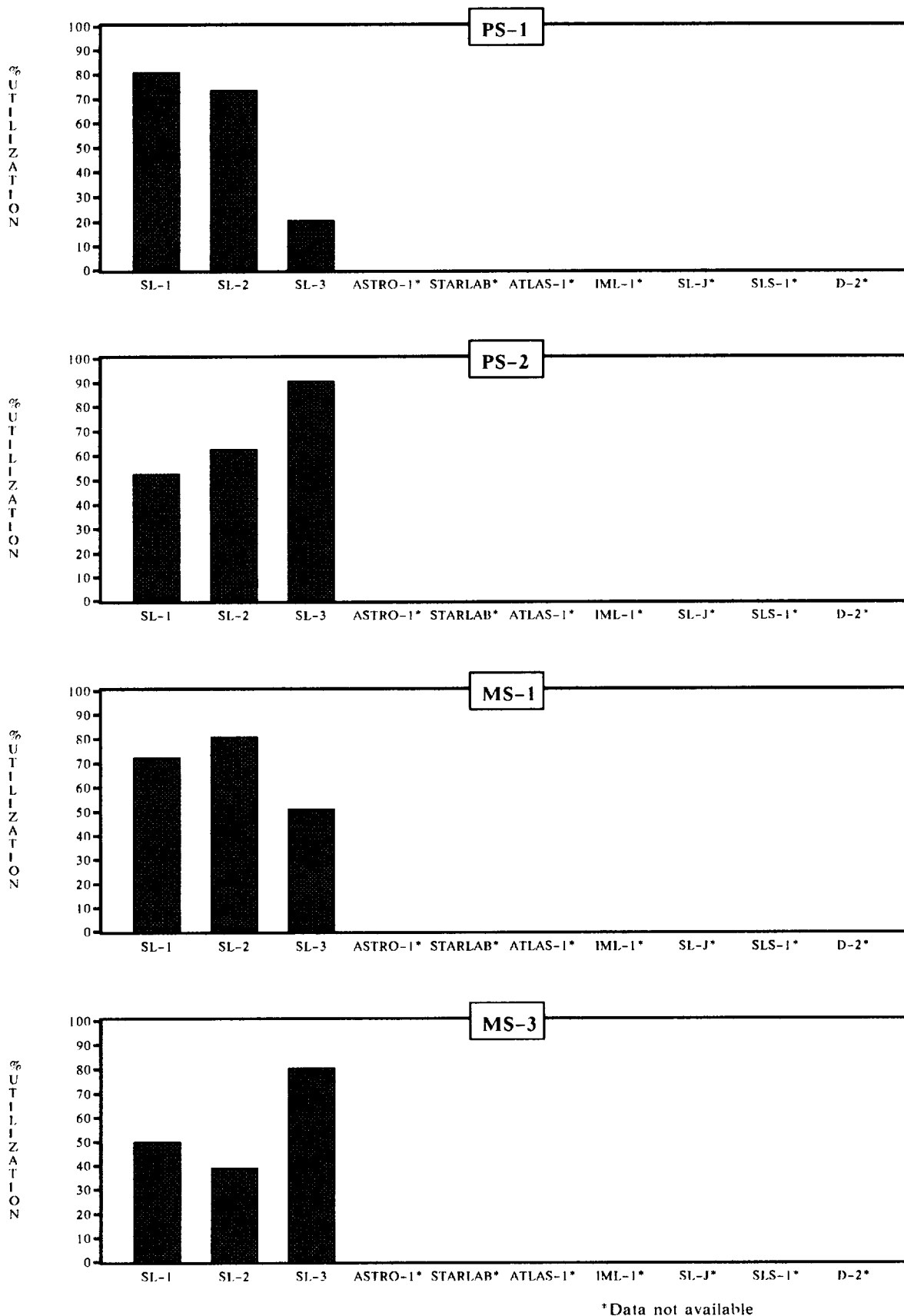


Figure 17. Final iteration FDI crew utilization.

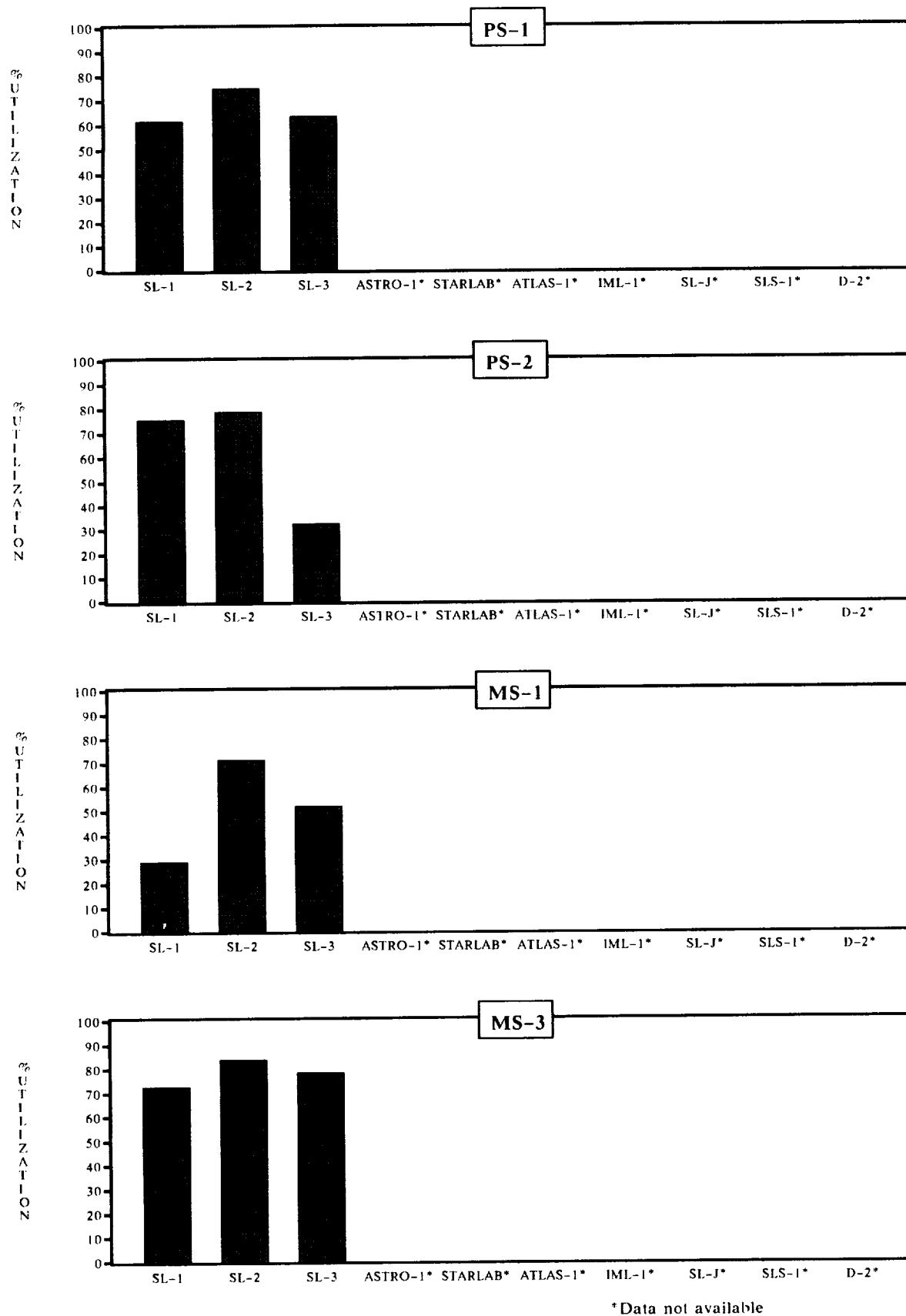


Figure 18. Final iteration FD2 crew utilization.

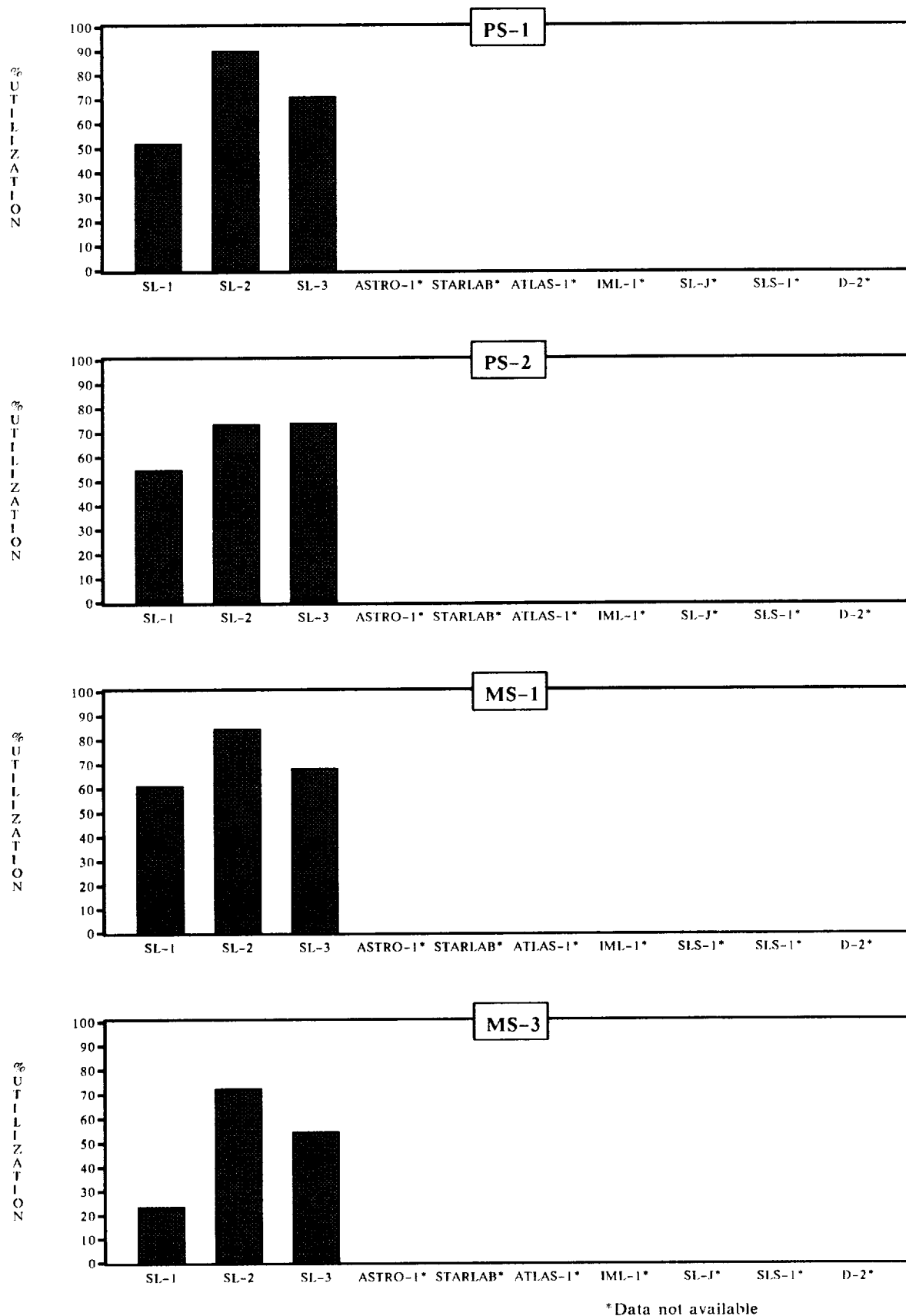
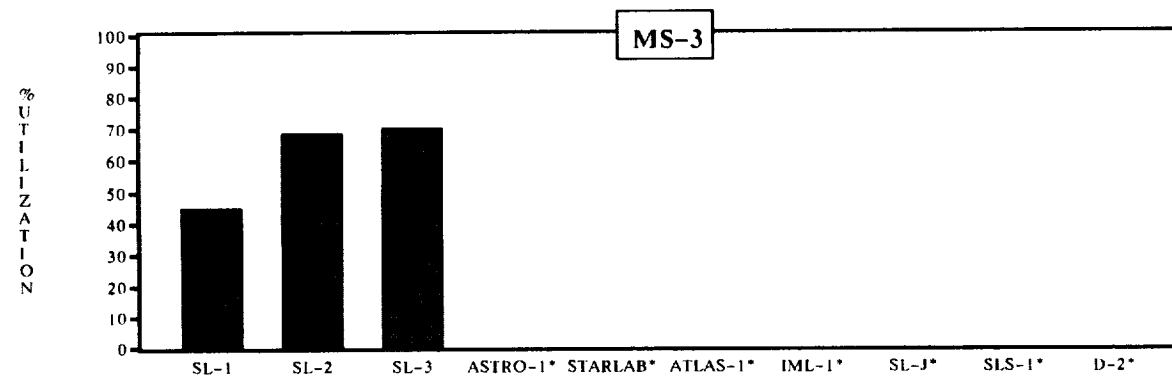
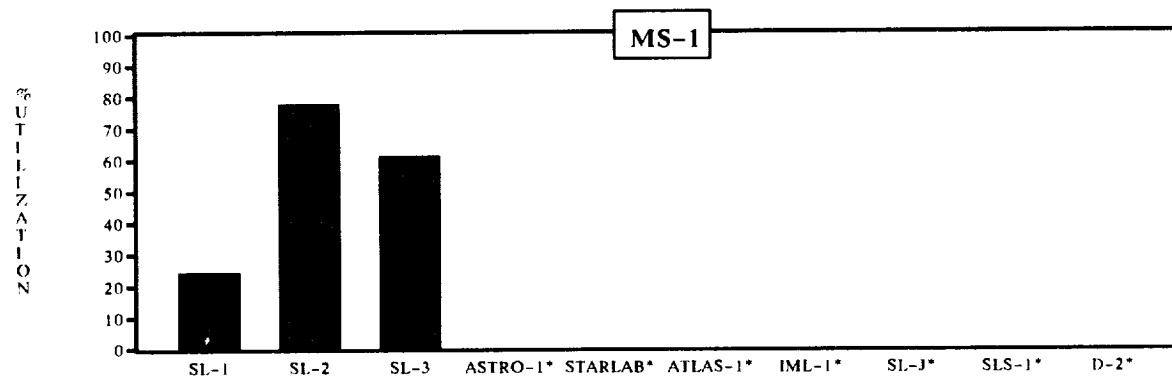
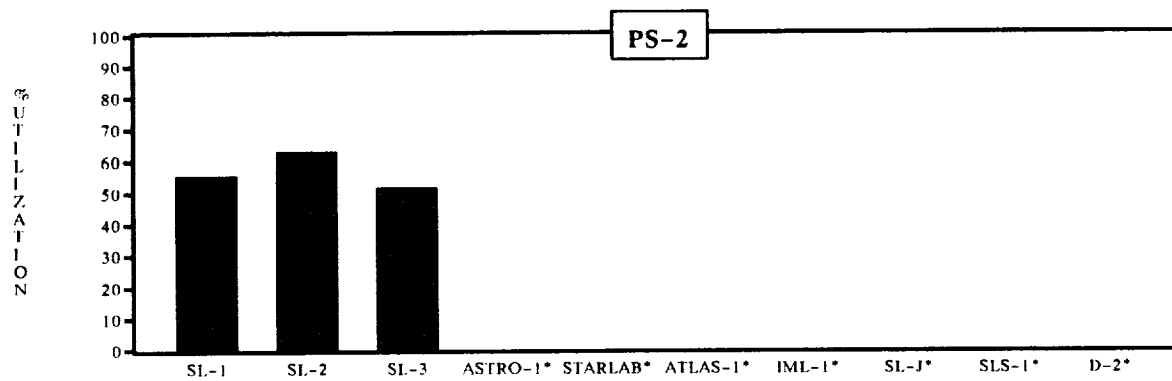
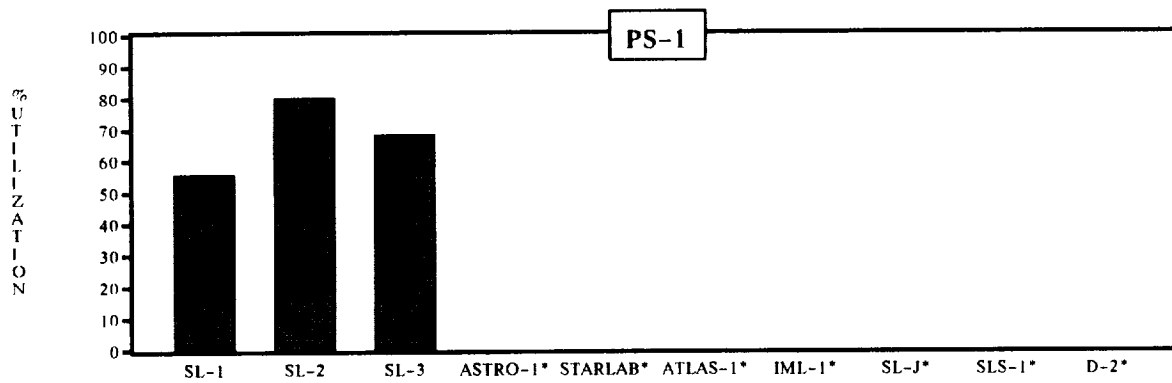


Figure 19. Final iteration FD3 crew utilization.



*Data not available

Figure 20. Final iteration FD4 crew utilization.

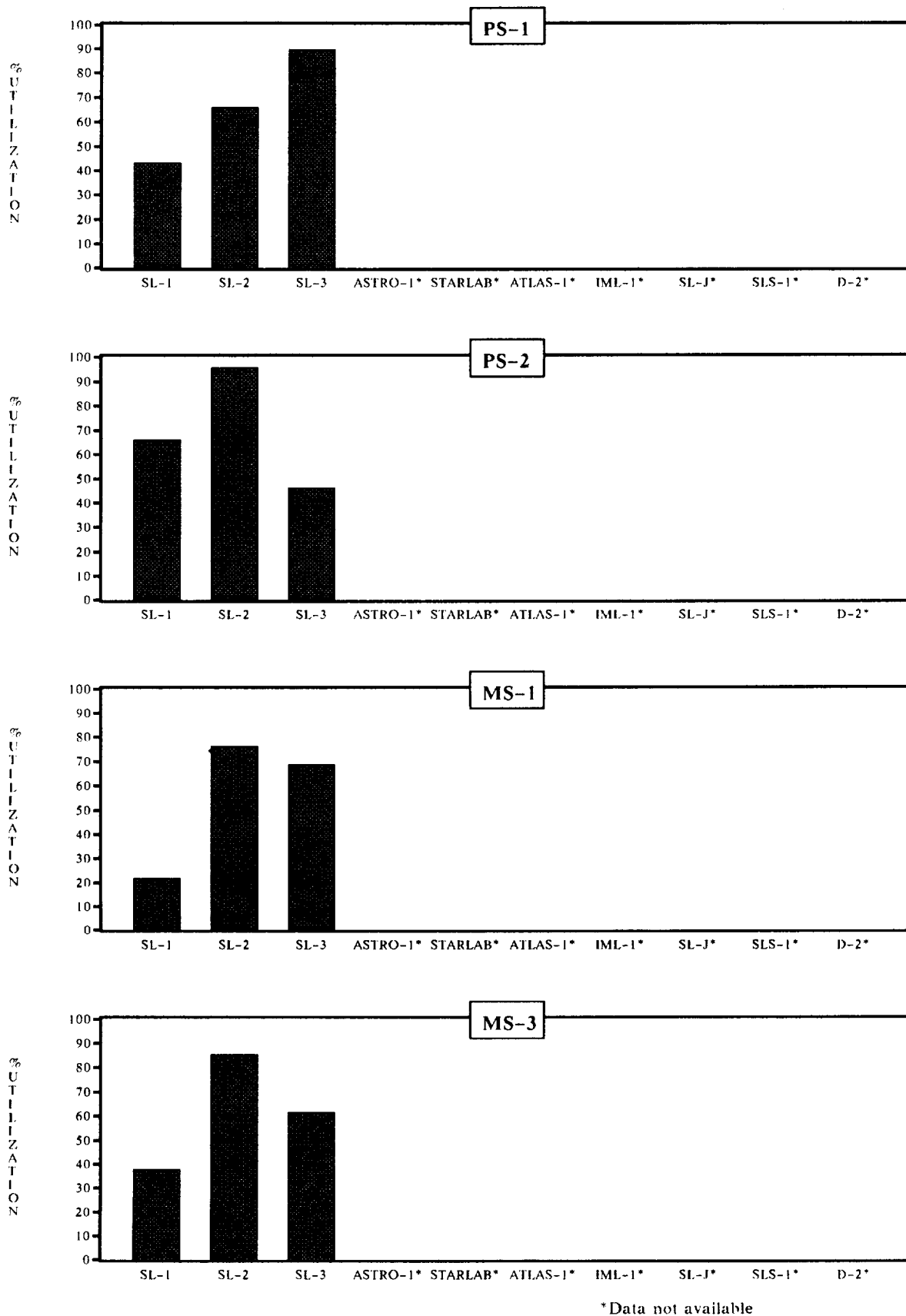


Figure 21. Final iteration FD5 crew utilization.

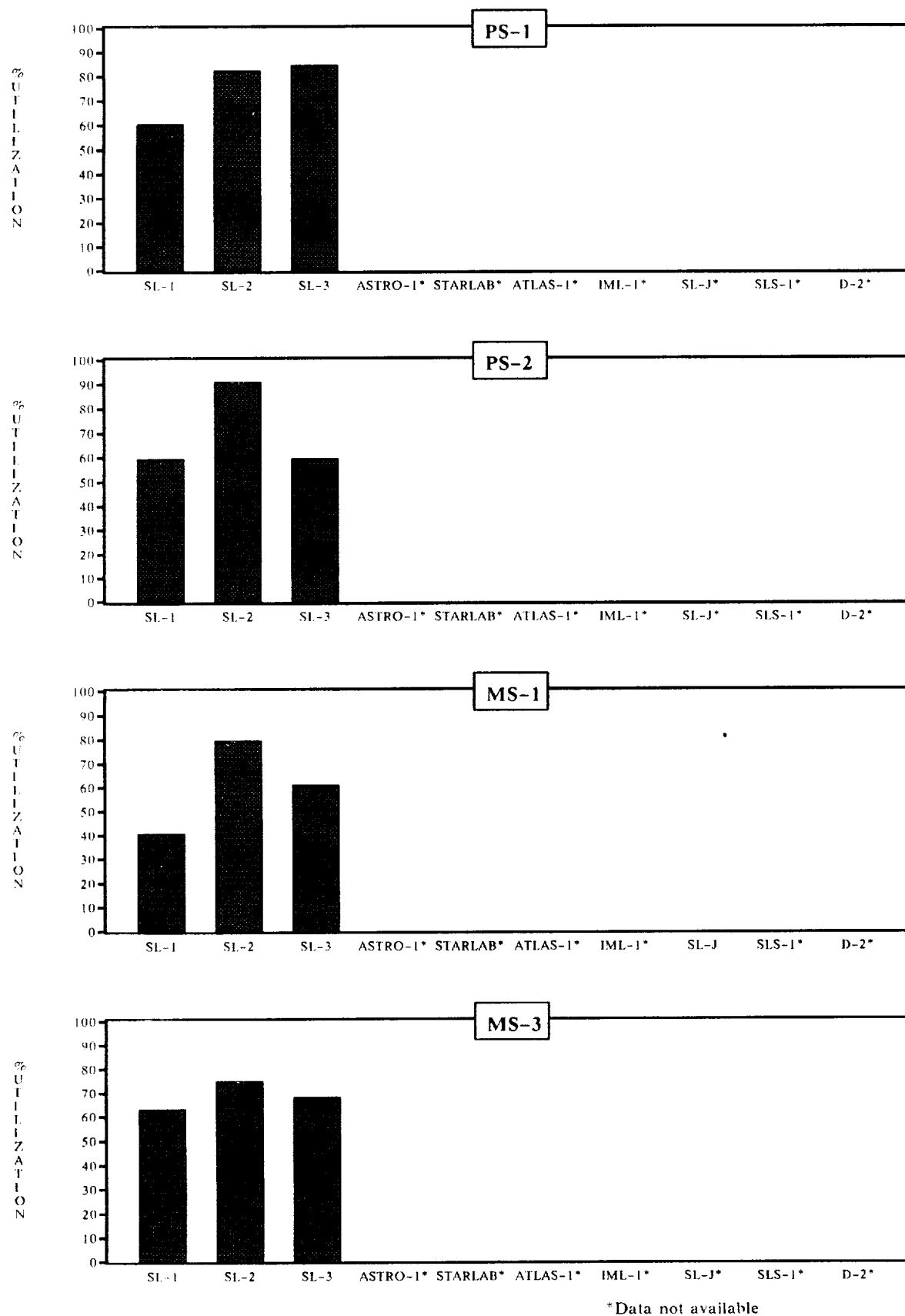


Figure 22. Final iteration FD6 crew utilization.

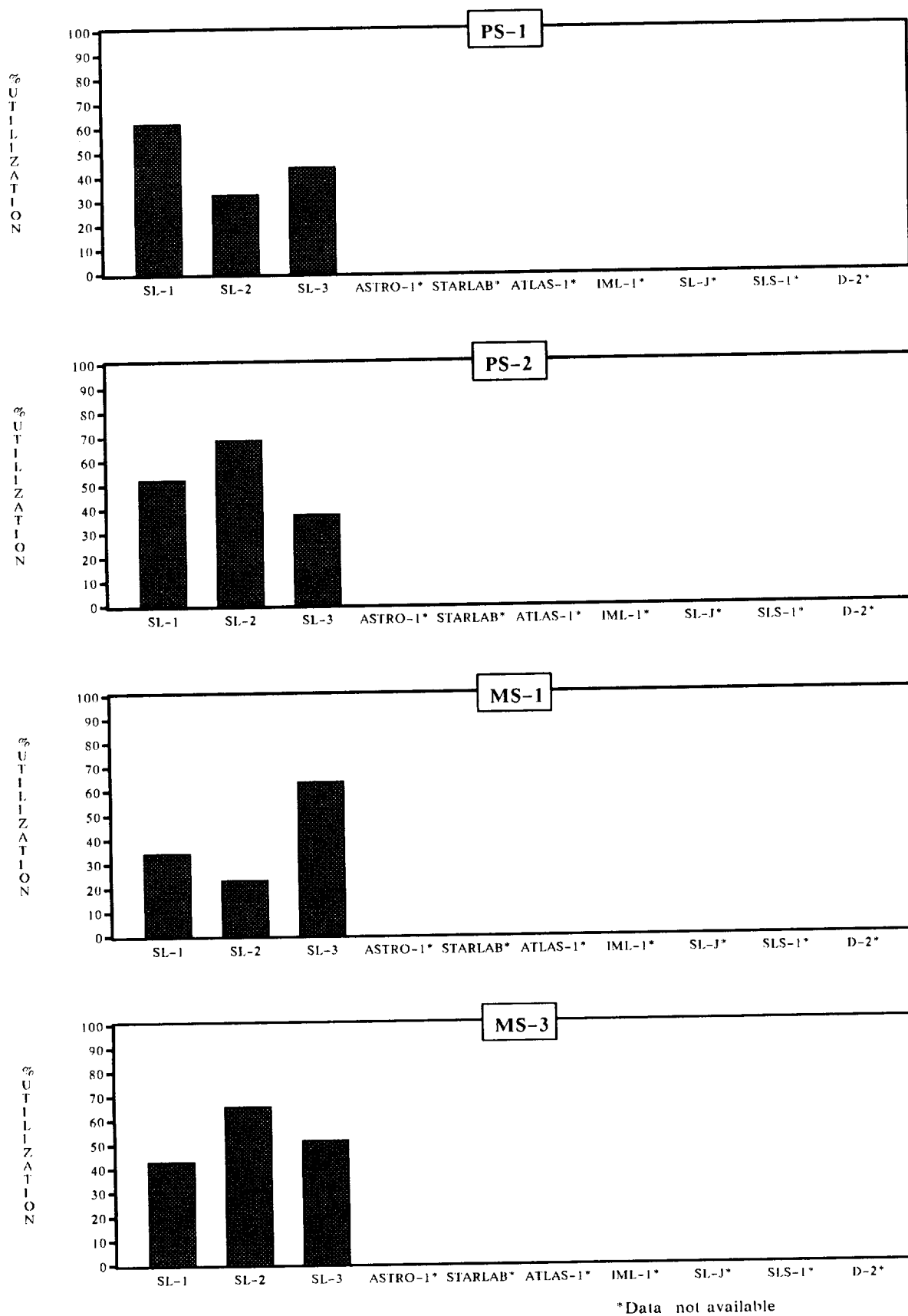


Figure 23. Final iteration FD7 crew utilization.

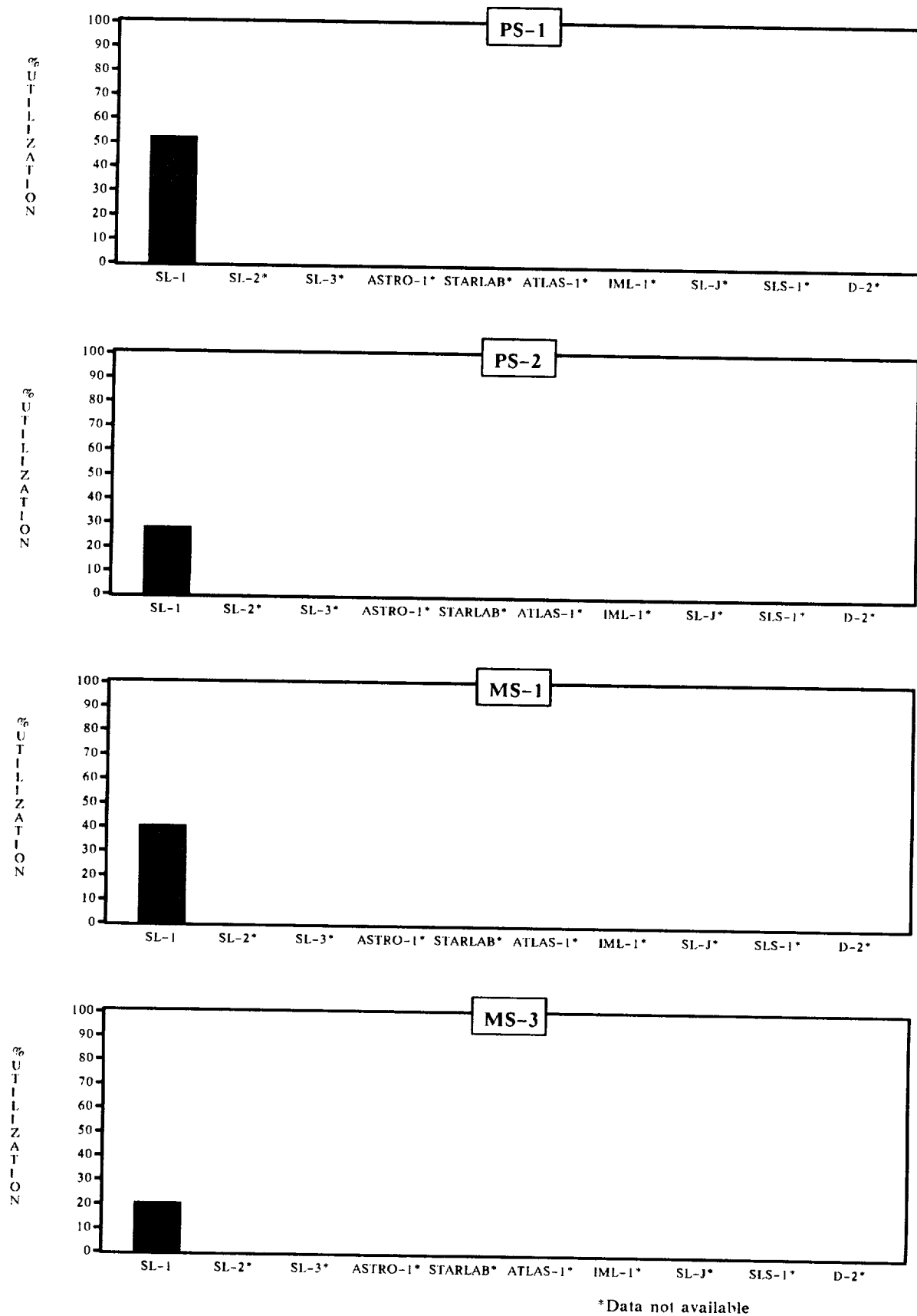


Figure 24. Final iteration FD8 crew utilization.

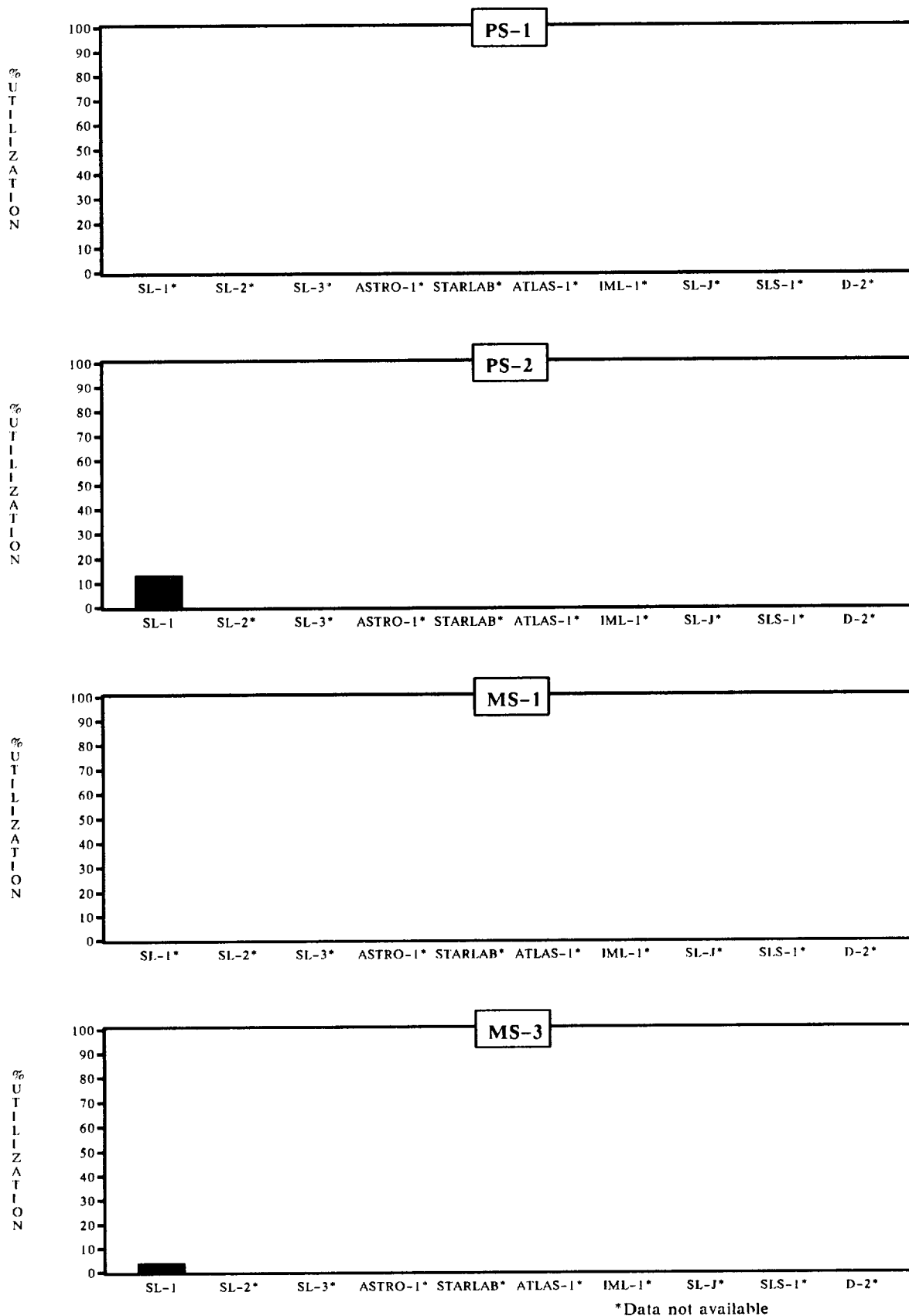


Figure 25. Final iteration FD9 crew utilization.

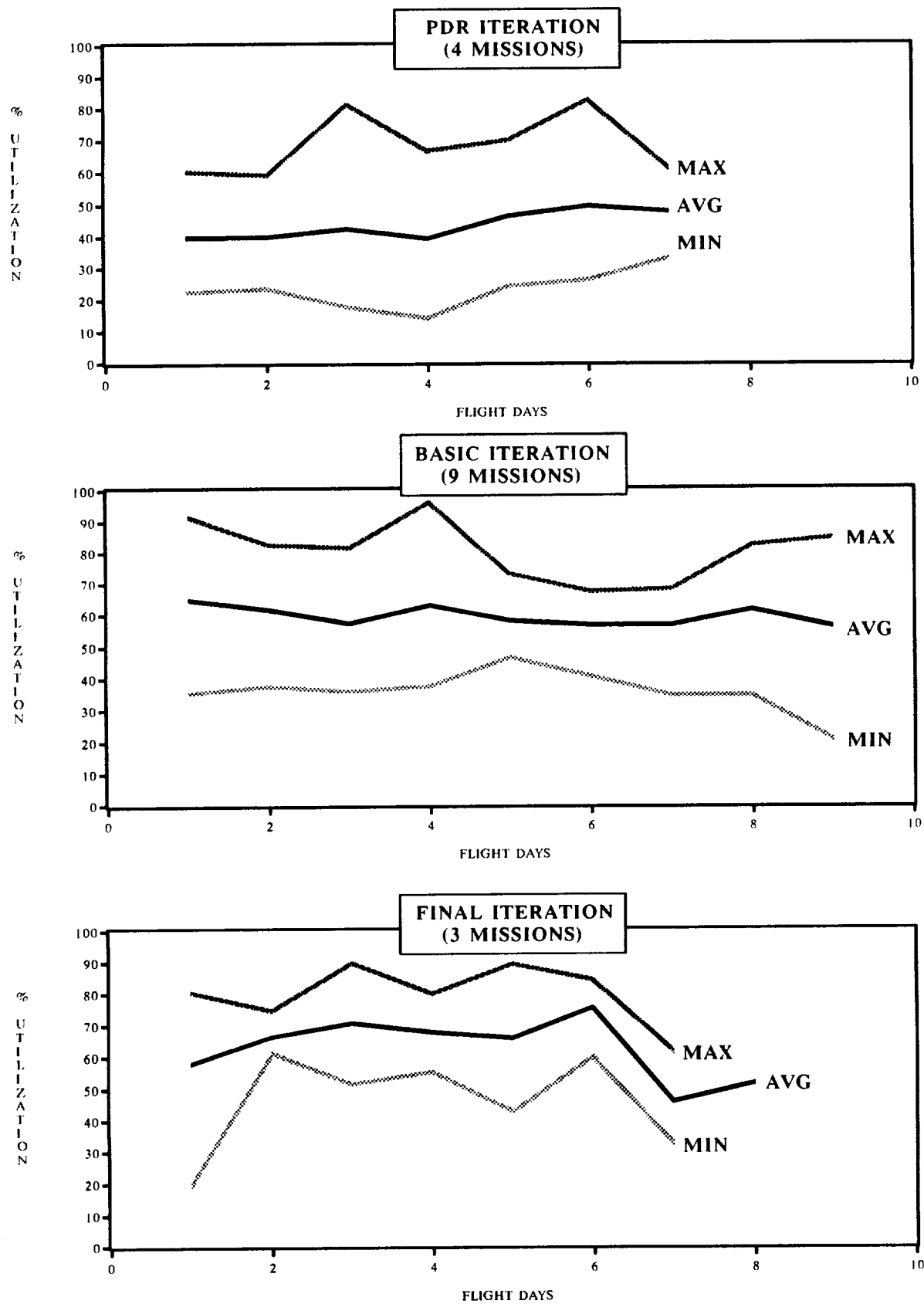


Figure 26. PS-1 crew utilization summary.

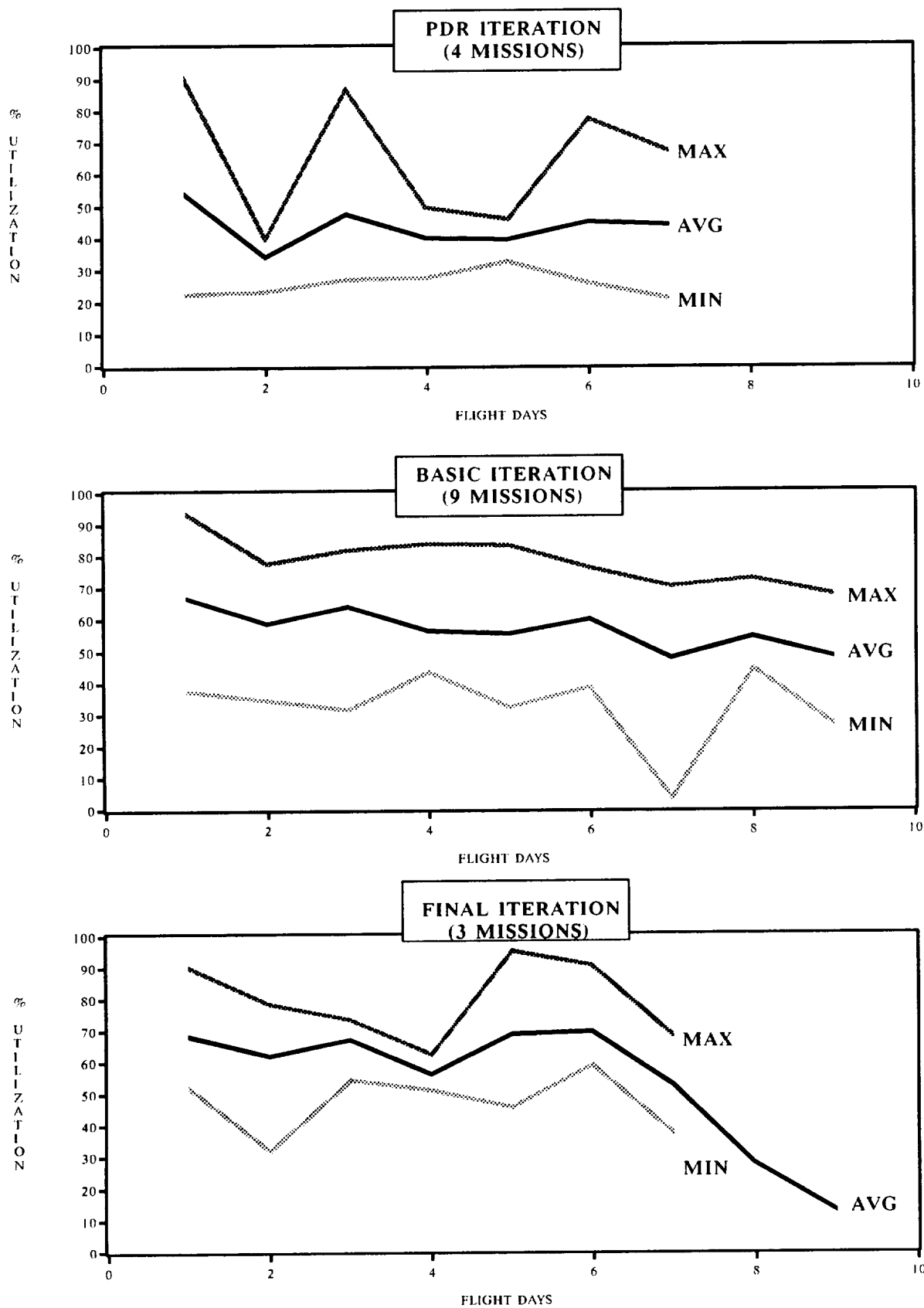


Figure 27. PS-2 crew utilization summary.

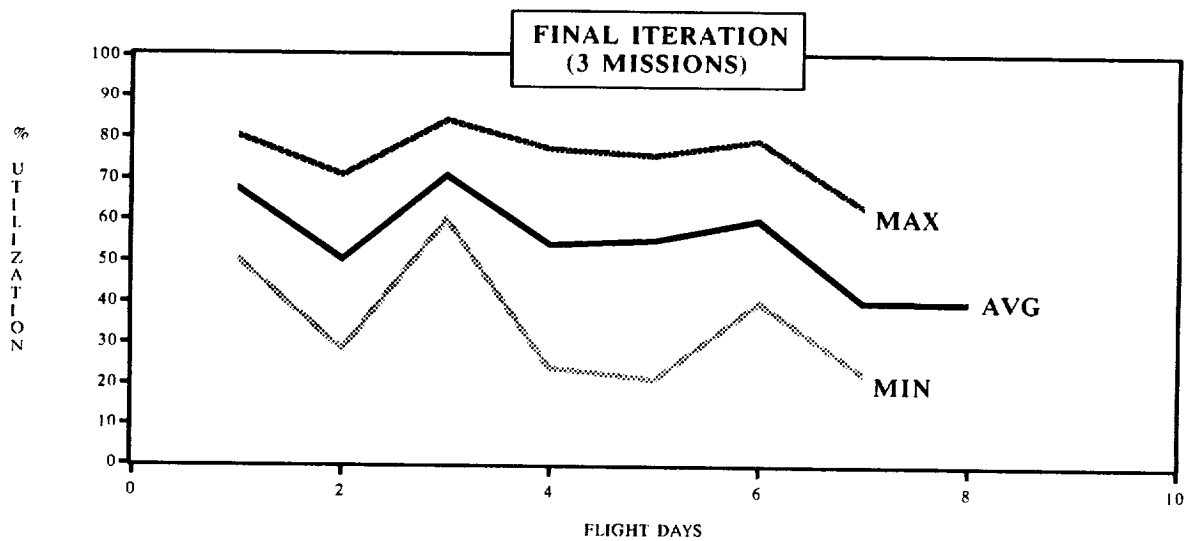
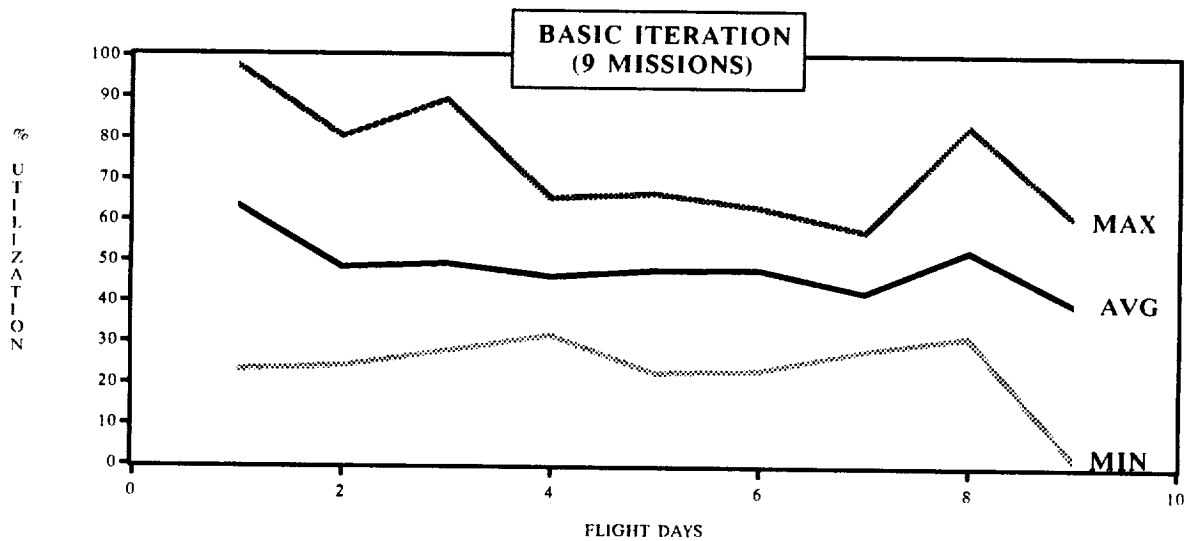
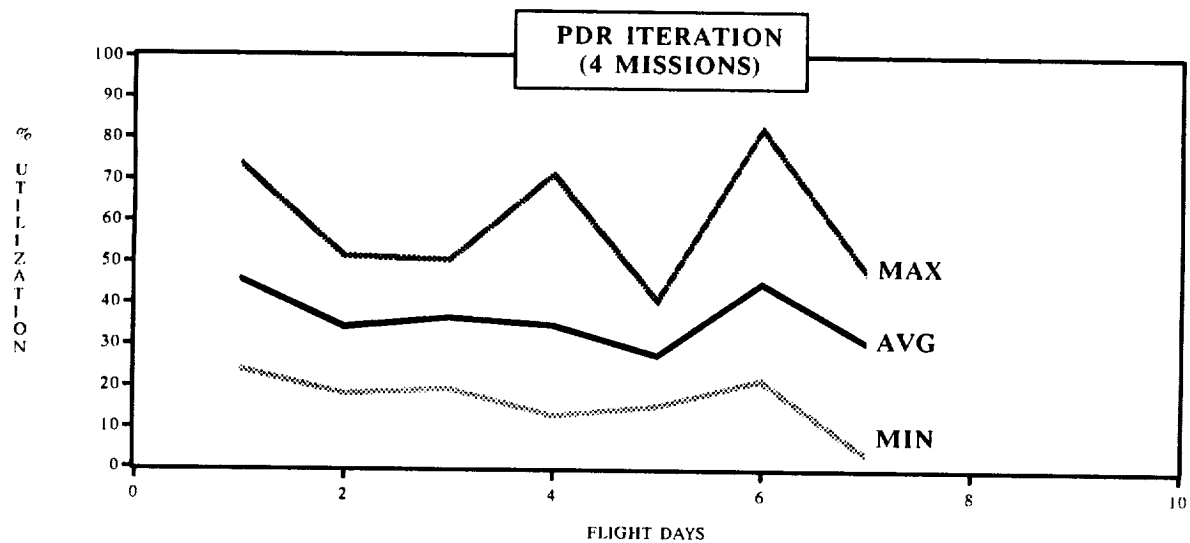


Figure 28. MS-1 crew utilization summary.

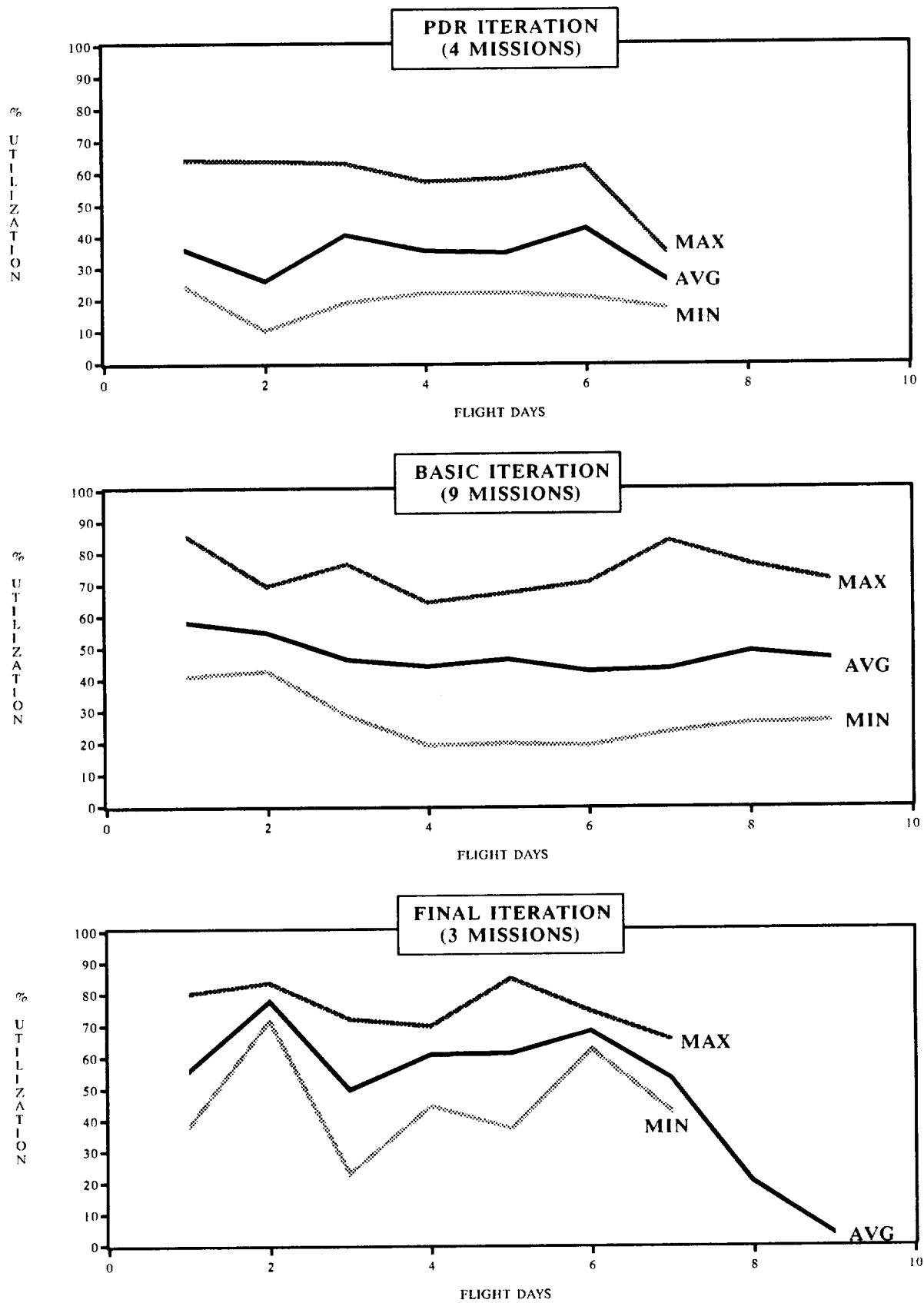


Figure 29. MS-3 crew utilization summary.

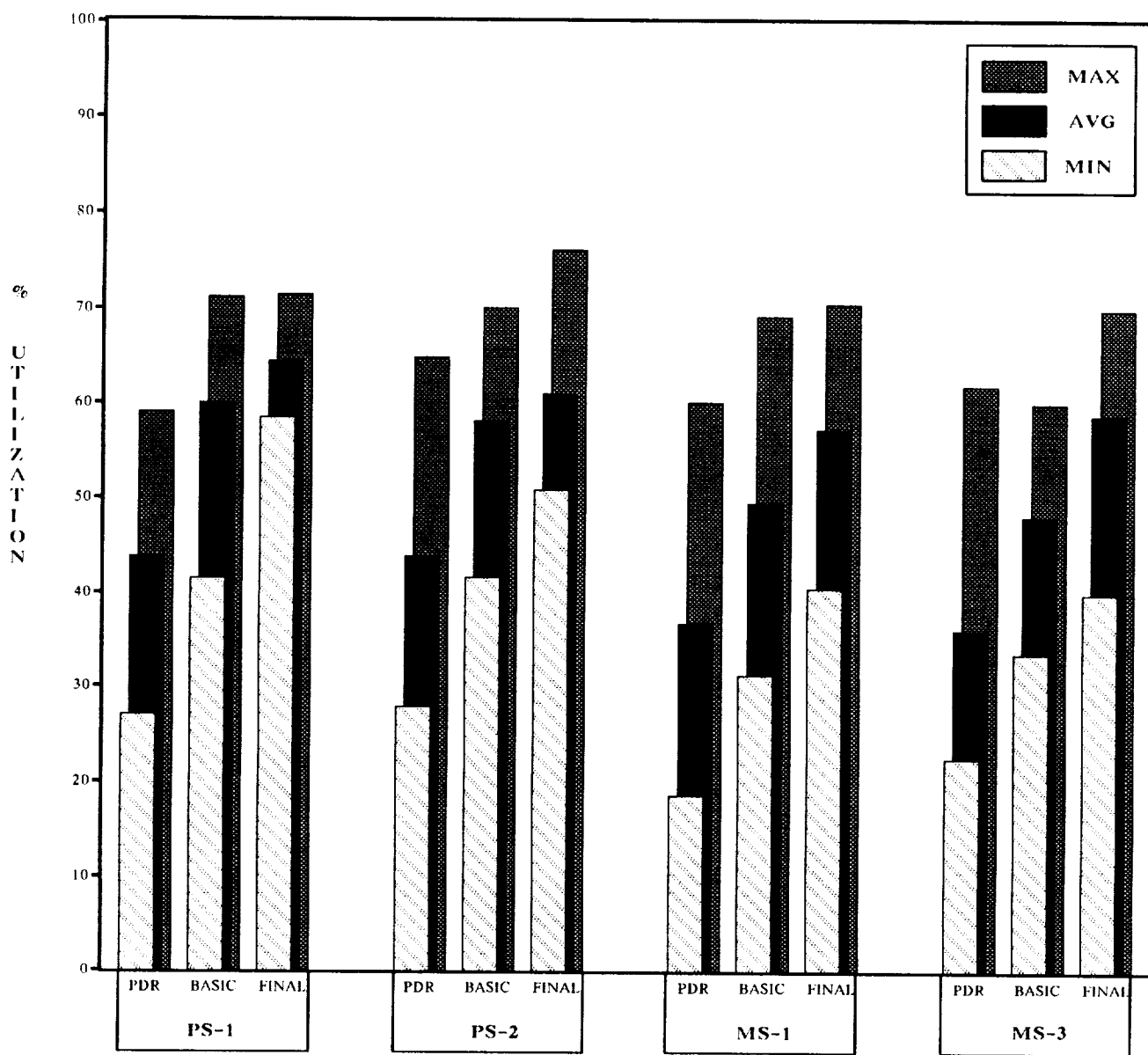


Figure 30. Crew utilization summary, all missions.

APPENDIX A

PAYLOAD CREW UTILIZATION ANALYSIS
(Percent Crew Time Per Day and Per Mission)

TABLE 1. PS-1 CREW UTILIZATION – RR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J	62.14	75.60	20.85	62.27	22.98	56.03	27.43	END	
SLS-1*									
D-2*									

*Data not available.

TABLE 2. PS-2 CREW UTILIZATION – RR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J	75.00	71.47	50.92	25.11	42.95	33.80	—	END	
SLS-1*									
D-2*									

*Data not available.

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TABLE 3. MS-1 CREW UTILIZATION – RR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J	44.05	43.55	65.11	45.96	44.11	63.12	14.74	END	
SLS-1*									
D-2*									

*Data not available.

TABLE 4. MS-3 CREW UTILIZATION – RR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J	39.67	56.90	83.26	52.20	17.05	83.26	—	END	
SLS-1*									
D-2*									

*Data not available.

TABLE 5. PS-1 CREW UTILIZATION – PDR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB	44.00	26.40	25.53	26.80	24.50	36.53	33.47	END	
ATLAS-1	22.76	23.83	18.01	14.47	40.78	26.52	42.60	END	
IML-1	60.71	51.63	45.67	66.95	51.06	82.97	54.29	END	
SL-J	33.10	59.57	81.70	50.78	70.21	53.24	61.60	END	
SLS-1*									
D-2*									
MIN	22.76	23.83	18.01	14.47	24.50	26.52	33.47	END	
AVG	40.14	40.35	42.72	39.75	46.63	49.81	47.99	END	
MAX	60.71	59.57	81.70	66.95	70.21	82.97	61.60	END	

*Data not available.

TABLE 6. PS-2 CREW UTILIZATION – PDR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB	29.25	23.67	27.48	27.94	32.92	26.15	—	END	
ATLAS-1	22.98	38.37	39.00	33.90	39.57	27.66	21.28	END	
IML-1	91.33	35.96	87.65	49.78	46.20	77.82	—	END	
SL-J	74.29	40.76	37.45	49.65	40.78	49.30	67.46	END	
SLS-1*									
D-2*									
MIN	22.98	23.67	27.48	27.94	32.92	26.15	21.28	END	
AVG	54.46	34.69	47.89	40.31	39.86	45.23	44.37	END	
MAX	91.33	40.76	87.65	49.78	46.20	77.82	67.46	END	

*Data not available.

TABLE 7. MS-1 CREW UTILIZATION – PDR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB	44.00	18.56	19.85	21.13	18.58	28.53	27.68	END	
ATLAS-1	24.39	18.87	31.35	13.48	15.81	22.13	4.26	END	
IML-1	74.28	49.36	51.06	72.05	41.70	83.54	48.90	END	
SL-J	41.90	51.77	45.11	34.04	36.17	48.03	44.37	END	
SL-1*									
D-2*									
MIN	24.39	18.56	19.85	13.48	15.81	22.13	4.26	END	
AVG	46.14	34.64	36.84	35.17	28.06	45.55	31.30	END	
MAX	74.28	51.77	51.06	72.05	41.70	83.54	48.90	END	

*Data not available.

TABLE 8. MS-3 CREW UTILIZATION – PDR ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1*									
SL-2*									
SL-3*									
ASTRO-1*									
STARLAB	29.25	18.23	19.31	22.26	24.76	21.02	—	END	
ATLAS-1	27.23	10.67	38.01	37.45	35.18	54.75	17.45	END	
IML-1	64.50	64.18	63.40	57.73	58.60	62.58	—	END	
SL-J	24.56	12.40	43.12	25.96	22.33	33.52	35.71	END	
SLS-1*									
D-2*									
MIN	24.56	10.67	19.31	22.26	22.33	21.02	17.45	END	
AVG	36.38	26.37	40.96	35.85	35.21	42.96	26.58	END	
MAX	64.50	64.18	63.40	57.73	58.60	62.58	35.71	END	

*Data not available.

TABLE 9. PS-1 CREW UTILIZATION – BASIC ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	82.15	60.00	40.71	63.83	51.06	58.12	57.59	63.27	76.43
SL-2*									
SL-3	63.44	53.04	60.56	96.45	49.79	67.65	51.60	END	
ASTRO-1	46.08	71.00	73.61	73.61	73.37	58.11	68.43	82.72	21.22
STARLAB	72.72	57.73	45.53	54.30	49.21	59.73	54.63	END	
ATLAS-1	50.00	38.00	57.00	38.00	47.00	41.00	35.00	35.00	33.00
IML-1	92.00	83.00	82.00	67.00	62.00	63.00	65.00	60.00	67.00
SL-J	35.85	58.64	64.18	50.71	57.00	51.49	56.93	END	
SLS-1	63.05	69.24	58.78	81.74	69.58	63.19	67.06	END	
D-2	81.05	67.47	36.45	43.97	66.66	51.48	57.16	68.36	85.07
MIN	35.85	38.00	36.45	38.00	47.00	41.00	35.00	35.00	21.22
AVG	65.14	62.01	57.64	63.29	58.40	57.08	57.04	61.87	56.54
MAX	92.00	83.00	82.00	96.45	73.37	67.65	68.43	82.72	85.07

*Data not available.

TABLE 10. PS-2 CREW UTILIZATION – BASIC ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	62.90	60.82	65.80	53.90	56.03	56.17	67.08	52.90	27.23
SL-2*									
SL-3	83.01	61.24	66.95	43.82	32.71	65.55	4.31	END	
ASTRO-1	61.30	34.96	64.16	52.90	49.19	62.83	63.03	45.03	43.56
STARLAB	66.35	51.34	46.52	51.02	44.39	63.54	70.58	END	
ATLAS-1	38.00	49.00	32.00	45.00	36.00	39.00	45.00	49.00	
IML-1	94.00	78.00	81.00	67.00	64.00	39.00	50.00	73.00	68.00
SL-J	71.83	68.03	82.20	84.12	83.69	74.96	25.96	END	
SLS-1	65.56	72.88	69.39	61.16	78.17	76.45	56.27	END	
D-2	61.52	56.02	71.40	52.19	57.87	65.42	51.47	54.26	55.64
MIN	38.00	34.96	32.00	43.82	32.71	39.00	4.31	45.03	27.23
AVG	67.16	59.14	64.38	56.79	55.78	60.32	48.18	54.83	48.60
MAX	94.00	78.00	82.20	84.12	83.69	76.45	70.58	73.00	68.00

*Data not available

TABLE 11. MS-1 CREW UTILIZATION – BASIC ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	71.24	37.88	28.79	32.20	35.04	36.52	31.77	55.64	51.43
SL-2*									
SL-3	74.25	54.51	70.78	65.67	67.09	57.10	48.66	END	
ASTRO-1	56.27	24.63	28.36	42.41	38.06	35.36	28.57	39.84	2.85
STARLAB	72.72	45.73	31.06	39.02	41.98	61.19	47.24	END	
ATLAS-1	51.00	46.00	44.00	50.00	54.00	46.00	33.00	32.00	36.00
IML-1	98.00	81.00	90.00	66.00	48.00	49.00	58.00	84.00	49.00
SL-J	23.63	43.29	34.11	33.47	23.02	23.75	37.53	END	
SLS-1	70.83	66.82	60.61	44.78	64.79	62.30	49.92	END	
D-2	57.17	39.77	60.59	47.09	61.84	63.72	50.38	54.26	61.66
MIN	23.63	24.63	28.36	32.20	23.02	23.75	28.57	32.00	2.85
AVG	63.90	48.84	49.81	46.73	48.20	48.32	42.78	53.14	40.18
MAX	98.00	81.00	90.00	66.00	67.09	63.72	58.00	84.00	61.66

*Data not available.

TABLE 12. MS-3 CREW UTILIZATION – BASIC ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	54.84	67.81	36.96	53.33	51.49	71.06	47.08	34.18	26.95
SL-2*									
SL-3	58.85	69.92	62.12	58.72	44.39	30.07	39.93	END	
ASTRO-1	53.69	43.94	29.02	37.16	32.70	26.38	23.63	26.51	28.83
STARLAB	51.47	43.12	44.49	29.52	36.45	45.34	84.31	END	
ATLAS-1	45.00	47.00	41.00	43.00	39.00	40.00	42.00	43.00	
IML-1	86.00	63.00	77.00	44.00	62.00	44.00	39.00	65.00	60.00
SL-J	41.32	48.04	53.48	19.57	20.15	19.50	40.58	END	
SLS-1	72.50	59.09	44.39	50.87	67.61	52.76	31.57	END	
D-2	62.45	54.95	31.77	64.68	66.24	57.58	45.53	76.73	71.74
MIN	41.32	43.12	29.02	19.57	20.15	19.50	23.63	26.51	26.95
AVG	58.45	55.20	46.69	44.53	46.67	42.96	43.73	49.08	46.88
MAX	86.00	69.92	77.00	64.68	67.61	71.06	84.31	76.73	71.74

*Data not available.

TABLE 13. PS-1 CREW UTILIZATION – FINAL ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	80.81	61.67	51.91	55.74	43.26	60.43	62.13	52.07	
SL-2	73.62	75.07	90.15	80.28	65.82	82.47	32.93	END	
SL-3	20.54	63.54	71.06	68.22	89.64	84.68	44.05	END	
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J*									
SLS-1*									
D-2*									
MIN	20.54	61.67	51.91	55.74	43.26	60.43	32.93		
AVG	58.32	66.76	71.04	68.08	66.24	75.86	46.37	52.07	
MAX	80.81	75.07	90.15	80.28	89.64	84.68	62.13		

*Data not available.

TABLE 14. PS-2 CREW UTILIZATION – FINAL ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	52.63	75.69	54.78	55.46	66.10	59.43	52.36	28.08	13.33
SL-2	62.67	78.84	73.68	62.86	95.56	90.93	68.73	END	
SL-3	90.63	32.57	73.90	51.48	46.04	59.71	37.83	END	
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J*									
SLS-1*									
D-2*									
MIN	52.63	32.57	54.78	51.48	46.04	59.43	37.83		
AVG	68.64	62.36	67.45	56.60	69.23	70.02	52.97	28.08	13.33
MAX	90.63	78.84	73.90	62.86	95.56	90.93	68.73		

*Data not available.

TABLE 15. MS-1 CREW UTILIZATION – FINAL ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	72.36	29.09	60.99	24.40	21.70	40.58	34.61	40.49	
SL-2	80.78	71.37	84.66	77.78	76.12	79.73	23.28	END	
SL-3	51.03	51.91	68.22	61.27	68.65	61.13	63.76	END	
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J*									
SLS-1*									
D-2*									
MIN	51.03	29.09	60.99	24.40	21.70	40.58	23.28		
AVG	68.05	50.79	71.29	54.48	55.49	60.48	40.55	40.49	
MAX	80.78	71.37	84.66	77.78	76.12	79.73	63.76		

*Data not available.

TABLE 16. MS-3 CREW UTILIZATION – FINAL ITERATION

	FD1 (%)	FD2 (%)	FD3 (%)	FD4 (%)	FD5 (%)	FD6 (%)	FD7 (%)	FD8 (%)	FD9 (%)
SL-1	50.00	72.64	23.62	44.96	37.73	62.98	43.06	20.57	3.97
SL-2	39.00	83.92	72.42	68.55	85.27	74.71	65.77	END	
SL-3	80.45	78.43	54.60	70.21	61.70	68.08	51.55	END	
ASTRO-1*									
STARLAB*									
ATLAS-1*									
IML-1*									
SL-J*									
SLS-1*									
D-2*									
MIN	39.00	72.64	23.62	44.96	37.73	62.98	43.06		
AVG	56.48	78.33	50.21	61.24	61.56	68.59	53.46	20.57	3.97
MAX	80.45	83.92	72.42	70.21	85.27	74.71	65.77		

*Data not available.

TABLE 17. CREW UTILIZATION SUMMARY – RR ITERATION

	PS-1 (%)	PS-2 (%)	MS-1 (%)	MS-3 (%)
SL-1*				
SL-2*				
SL-3*				
ASTRO-1*				
STARLAB*				
ATLAS-1*				
IML-1*				
SL-J	46.75	49.87	45.80	55.39
SL-1*				
D-2*				

*Data not available.

TABLE 18. CREW UTILIZATION SUMMARY – PDR ITERATION

	PS-1 (%)	PS-2 (%)	MS-1 (%)	MS-3 (%)
SL-1*				
SL-2*				
SL-3*				
ASTRO-1*				
STARLAB	31.03	27.90	25.47	22.47
ATLAS-1	26.99	31.82	18.61	31.53
IML-1	59.04	64.79	60.12	61.83
SL-J	58.60	51.38	43.05	28.22
SLS-1*				
D-2*				
MIN	26.99	27.90	18.61	22.47
AVG	43.91	43.97	36.81	36.01
MAX	59.04	64.79	60.12	61.83

*Data not available.

TABLE 19. CREW UTILIZATION SUMMARY – BASIC ITERATION

	PS-1 (%)	PS-2 (%)	MS-1 (%)	MS-3 (%)
SL-1	61.46	55.87	42.27	49.30
SL-2*				
SL-3	63.21	51.08	62.58	52.00
ASTRO-1	63.12	52.99	32.92	33.54
STARLAB	56.26	56.24	48.42	47.81
ATLAS-1	41.55	41.62	43.55	42.50
IML-1	71.22	68.22	69.22	60.00
SL-J	53.54	70.11	31.25	34.66
SLS-1	67.52	68.55	60.07	54.11
D-2	61.96	58.42	55.16	59.07
MIN	41.55	41.62	31.25	33.54
AVG	59.98	58.12	49.49	48.11
MAX	71.22	70.11	69.22	60.00

*Data not available.

TABLE 20. CREW UTILIZATION SUMMARY – FINAL ITERATION

	PS-1 (%)	PS-2 (%)	MS-1 (%)	MS-3 (%)
SL-1	58.50	50.87	40.52	39.94
SL-2	71.47	76.18	70.53	69.94
SL-3	63.10	56.02	60.85	66.43
ASTRO-1*				
STARLAB*				
ATLAS-1*				
IML-1*				
SL-J*				
SLS-1*				
D-2*				
MIN	58.50	50.87	40.52	39.94
AVG	64.35	61.02	57.30	58.77
MAX	71.47	76.18	70.53	69.94

*Data not available.

TABLE 21. SUMMARY CREW UTILIZATION AT MAJOR TIMELINE ITERATIONS

Iteration	Number of Missions	PS-1 (%)	PS-2 (%)	MS-1 (%)	MS-3 (%)
RR	1	46.75	49.87	45.80	55.39
PDR	4	43.91	43.97	36.81	36.01
BASIC	9	59.98	58.12	49.49	48.11
FINAL	3	64.35	61.02	57.30	58.77



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16. Abstract <p>This study analyzed planned payload crew utilization on Spacelab missions for the primary purpose of establishing trends and guidelines. The study included missions that have flown to date as well as those in planning. Available data were analyzed on the basis of four major timeline iterations that occur during mission design. Data were categorized and assessed by crewmember, flight day, and mission. Based on the results of this analysis it was recommended that for the Requirements Review (RR) and Preliminary Design Review (PDR) iterations the maximum utilization per shift should be 75 percent for the Payload Specialist (PS) and 65 percent for the Mission Specialist (MS); and for the basic and final iterations, the maximum utilization per shift should be 85 percent for the PS and 75 percent for the MS. Additional recommendations include limiting the amount of activity during the first two shifts whenever possible and establishing a common set of guidelines for the calculation of crew utilization.</p>			
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